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# CHEMICAL LECTURES,

Publickly Read at LONDON,

In the Years 1731, and 1732;

And since at SCARBOROUGH, in 1733;

For the IMPROVEMENT of

ARTS, TRADES, and NATURAL PHILOSOPHY.

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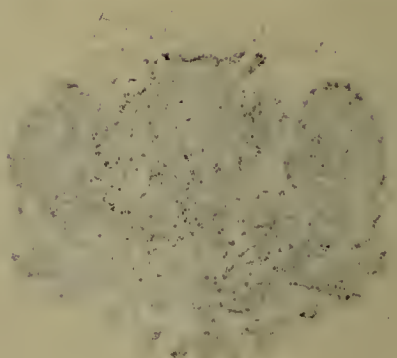
By *PETER SHAW*,
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Right Honourable the

# Lord Viſcount *Lonſdale*,

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MY LORD,

AS your Lordſhip was pleaſed to honour theſe Lectures with your Notice in Manuſcript, I take the Liberty of laying them before you in Print; being deſirous the Publick ſhou'd know, that their Deſign was approved of by ſo unexceptionable a Judge.

For, beſides your uncommon Skill in Civil Policy, the Laws, and all the Branches of Publick Buſineſs; you have, like the Illuſtrious Lord *Bacon*, a Talent for the Improvement of Arts, and a Pleaſure, and Sagacity, in purſuing natural Enquiries.

Were I not, therefore, ſenſible, my Lord, that your Candour is as extenſive as your Learning, I ſhou'd be cautious of thus ſubmitting theſe ſlender Enquiries to your View; as they are neither conducted in a manner ſuitable to your correct and exquiſite Taſte; nor purſued to ſuch a length, as your great Knowledge in Philoſophical Matters may juſtly require.

But this gives me farther Encouragement, that I do not know a more uſeful Subject, than the preſent, to a Trading

ding Nation; nor a Perſon better qualified than your Lordſhip, to perceive its Tendency, and direct its Improvement.

*I am,*

MY LORD,

YOUR LORDSHIP'S

*Moſt Obliged, and*

*Devoted Humble Servant,*

Peter Shaw.

# ADVERTISEMENT.

*THE following Lectures have had the Honour to be read before a noble Audience, who candidly overlooked their Failings, and requested their Publication.*

*As the Design is of large Extent, little more than a Sample of the whole cou'd, at present, be given: the farther Improvement of it being left to others.*

*The Experiments here employ'd, tho' many of them new, are generally simple; or performable with little Cost, and Apparatus: But if a few particular Instruments, and Trials, hereafter intimated, were to be made, and properly used, much greater Discoveries might be reasonably expected.*

A

# GLOSSARY:

OR,

## Explanation of the TECHNICAL TERMS in this Work.

*Acid.* By *Acids* are meant all thoſe things that taſte ſour; as Vinegar, Tartar, Juice of Crabs, Lemons, *&c.* Spirit of Nitre, Spirit of Salt, *&c.* and which when mixed with a due Proportion of an *Alkali*, conſtitute a neutral Body; wherein neither *Acid* nor *Alkali* prevails; whence it alters not the Colour of Syrup of Violets. *See* Alkali *and* Neutrals.

*Adits.* *See* Burrows.

*Alcohol.* Is pure and perfect Spirit of Wine, without the leaſt Particle of Water, or Phlegm.

*Alkali.* Is a word of extenſive Signification, and chemically denotes a large Tribe of Bodies. For all Bodies may be chemically conſider'd under three Tribes; or as being either *Alkali's*, *Acids*, or *Neutrals*. *Alkali's* have this eſſential Property, that when mixed, or united, with *Acids*, they conſtitute *Neutrals*. But a more common Mark of an *Alkali* is, that it turns Syrup of Violets green, as an *Acid* turns it red; whilſt the Admixture of a *Neutral* Body does

not alter the Colour of that Syrup. Thus Pot-Aſh, Salt of Tartar, and all fixed vegetable Salts; as likewiſe all volatile animal Salts and Spirits, are artificial *Alkalies*; as Chalk, the teſtaceous Bodies, *&c.* are natural *Alkalies*. And thus, in the vegetable Kingdom, Onions, Leeks, Garlick, Muſtard, *&c.* are *Alkaline*; as Sorrel, Wood-Sorrel, the Juice of Lemons, Oranges, Verjuice, *&c.* are *Acid*. Their Difference alſo is manifeſt from the Taſte, when the Habit of thus diſtinguiſhing them is acquir'd. *See* Acids *and* Neutrals.

*Amalgamation.* Is the Diſſolution, or Mixture of any Metal with Quick-ſilver: But Iron, of all the Metals, will not amalgamate, or unite therewith.

*Aſſaying.* Is the Art of diſcovering how much pure Metal is contain'd in any Ore, or Coin, aſſign'd. Hence *to make an Aſſay*, is to produce a Lump, or Grain, of pure Metal, from any ſmall quantity of Ore, or Coin.

*Axioms.* By *Axioms* are meant a kind of Corollaries, Conſequences, or Reſults, of certain Experiments, Facts, Obſervations, or particular Doctrines; ſo as to recapitulate a certain uſeful Truth, contained in a preceding part of the Work, and ſet it in a clearer light, with regard to Theory, or Speculation: As Canons, or Rules, regard Experience or Practice. *See* Canons.

*Balneum Mariæ.* Or Water-Heat, is no more than a Veſſel of Water, ſet in a Furnace, or over the Fire, with another Veſſel put into the Water; which latter Veſſel contains the Matter, or Subject, of the Operation.

*Buddling-Diſhes.* Are ſhallow Diſhes, like the Baſons of a pair of Scales, for the waſhing of Ores by the hand. *Burrows.*

*Burrows.* In Mining, are the Paſſages leading into a Mine, and cut thro' the Sides of a Hill, or Mountain, ſo large that the Workmen may conveniently wheel out the Ore in Barrows, or carry it along in Baſkets.

*Calcination.* Is the burning of a Body in an open Fire, in order to diſcharge its more volatile Parts, or reduce it to Powder.

*Canons.* Are Rules of Practice, or Directions, for producing Effects, or performing Operations; and have the ſame regard to Practice, as Axioms have to Theory. *See* Axioms.

*Caput Mortuum.* Is that part of the Matter, which remains behind after Diſtillation, or Sublimation.

*Cementation.* Is the cloſe burning of a hard or metalline Body, with certain opening Powders, ſtrew'd betwixt its groſſer parts; ſo as to ſoften, tinge, or impregnate them, with the Fumes of ſuch Powders; or it is the Introduction of any Mineral, or Metallic Fumes into the ſolid Plates of a Metal, by means of a proper Heat, applied to a cloſe Veſſel, or double Crucible, wherein the Plates are laid, with the pulverized Matter ſtrew'd between them.

*Clarification.* *See* Depuration.

*Concentrating.* Is bringing the required Parts of a Subject cloſer together; as Salt-Water is concentrated by evaporating of the aqueous Humidity; and Wine by freezing out, or ſeparating its Water, in the form of Ice.

*Copelling*, or *Cupelling.* Is putting metallic Matters upon a cover'd Veſſel of Bone-Aſhes in a naked Fire, to try what Gold or Silver they will afford.

*Cryſtallization.* Is the Operation, whereby Salts diſſolv'd in Water ſhoot into Glebes, of particular

ticular Figures, according to the Nature of each Salt.

*Decantation.* Is the pouring off a clearer Liquor from a groſſer Sediment, after ſtanding.

*Deflagration.* Is ſetting exploſive Matters on fire in a Crucible, or other Veſſel, and ſuffering them to burn out; as when Nitre, or Tartar, are thrown into a red-hot Crucible, or to any melted Matter, whilſt it continues in the fire.

*Depuration.* Is the making of any matter pure, or freeing it from the Droſs, Dirt, or other heterogeneous Parts, wherewith it may happen to be mixed: So Honey is depurated, or clarified, by heating it, and taking off the Scum that riſes to the top.

*Digeſtion.* Is ſuffering ſolid and liquid, or groſſer and finer Matters, to ſtand together in a gentle Heat for ſome time, that the Liquor may extract the Virtues of the ſolid Ingredients; or the whole become more ſubtile and uniform.

*Diſtillation.* Is the raiſing of Liquids into Vapour by Heat; and condenſing that Vapour into a Liquid again.

*Elæoſaccharum.* Is an intimate Mixture of any eſſential Oil, with Sugar; by grinding them together in a Mortar.

*Elements.* *See* Principles.

*Elixation.* Is the waſhing a Matter with Water, in order to get out what will diſſolve therein.

*Empyreuma.* Is a nauſeous Taſte, or Odour, proceeding from the Subject being ſcorched or over-heated, in the Operation; as when Milk is burnt to, as they call it.

*Eſſential,* or *Chemical Oils.* Are the native Oil of Vegetables, drawn from them by Diſtillation with Water.

*Evaporation.* Is the ſetting a Liquor in a gentle Heat

Heat, to discharge its superfluous Humidity, or obtain its dry Remainder.

*aints.* Are the Liquor that runs from the Still, upon distilling any inflammable Spirit, after all the Proof-Spirit is come over. *See* Proof.

*iltration.* Is suffering any Liquor to pass thro' Cap-Paper, or rather a peculiar kind of filtring Paper, into a clean Vessel, or Glass; the Paper being cut Conically for the purpose, and put into a Glass Funnel, or laid upon a Stone Colander, or Strainer.

*orm.* Is the particular Act, or Law of Nature, whereby any thing exists.

*lux.* Is any matter added to an Ore, or metallic Matter, in order to make it melt, or run the easier, and yield a greater Quantity, or a purer Metal.

*ulmination.* Is the same as *Deflagration*, which see.

*using.* Is the same as Melting, being a Term generally applied to the melting of Metals, and metallic Matters, with a strong Heat.

*solation.* Is suffering Matters to stand and digest in the Heat of the Sun, instead of using the Heat of a Furnace.

*ac*, or *Laque.* Is a kind of Extract, or thick Body of Colour, prepar'd chiefly from vegetable Subjects, for Painters use. Of these *Laques* there are several Sorts; but in a more particular Sense, it signifies the *Red Laque* obtained by boiling *Stick-Lac* in Water.

*avadero's.* In Mining, are the Houses, or large Troughs, where the Ore is washed.

*imation.* Is the filing of a Metal, or metallic Substance, so as to reduce it into small Parts, called the Filings of that Metal.

*ixivium.* Is the same thing as Lee, or a Solution

lution of Salts, by boiling any ſaline Matter i
Water.

*Load.* In Mining, is the ſame as Ore.

*Lotion.* Is the waſhing of a Body in Water, t
get out its Salt, or whatever elſe will diſſolv
in Water.

*Low-Wines.* Are a weak Spirit, or the fir
Runnings of the Still, in diſtilling Brandies c
Spirits, from Waſh or Wines, and mix'd alon
with the ſecond Running, or more watry part.

*Menſtruum.* Is any Body applied to another, ſ
as to diſſolve it, and intimately mix its Par
with the Parts of the other: in which reſpe
the former may be called the *Solvent*, and th
latter the *Solvend.*

*Mercury.* Is another Name for *Quickſilver.*

*Metallurgy.* Includes the whole Art of workin
Metals from the Ore to ſaleable Metal.

*Muffle.* Is an arched earthen Inſtrument mad
to cover a Teſt, in Cupelling, ſo as that th
Coals, or Aſhes of the Fire, may not fall i
upon the Subject. *See* Cupelling.

*Muſt.* Is the unfermented Juice of the Grape
or any other liquid fermentable Subſtance, b
fore it enters the Act of Fermentation. *S*
Stum.

*Neutrals*, or *Neutral Bodies.* Are ſuch Bodies
manifeſt no Signs of either *Alkali*, or *Aci*
upon any of the Trials known, and allow'
to diſcover them; as particularly not by th
Taſte, or the Admixture of Syrup of Violet
*&c.* *See* Acid *and* Alkali.

*Per Deliquium.* Is the running of diſſolvab
things into Liquor, by barely expoſing the
to the open Air, or to the moiſt Air of a Cella

*Phlegm.* Is the ſame as Water, or aqueous L
quor.

*Pr*

*ecipitation.* Is the depoſiting of a Sediment; either by a Liquor ſtanding at reſt, or when any addition is us'd for the purpoſe.

*inciples.* Are the different ſimple Matters, whereof a Body is compos'd.

*oof.* In Spirits is meant of a certain Trial, or way of examining their Strength, by the Bubbles that ariſe on their Surface upon ſhaking them in a Phial.

*iartation.* Is the ſeparating of Gold from Silver, by means of *Aqua-Fortis* or *Aqua-Regia.*

*inteſſence.* Is the Mixture of an eſſential Oil with *Alcohol.*

*ctification.* Is purifying a Subject, by repeating the Operations, as Brandy is purified, or ſeparated, from its Phlegm, by repeated Diſtillation.

*duction.* Is the *reducing*, or recovering a Metal from its *Calx*, or *Aſhes*; and may likewiſe be applied, when any Body deſtroyed, as to its natural Form, or Appearance, is made to aſſume that Form again.

*frigeratory.* Is a Veſſel of cold Water, thro' which a winding metalline Pipe takes its Courſe, from the Hot Still, ſo as to bring off the Liquor cool, by Diſtillation.

*gulus.* Is an impure, or imperfect metallic Subſtance, that falls to the bottom of the Crucible in the melting of Ores, or impure metallic Subſtances.

*ria.* *See* Slag.

*arating-Glaſs.* Is a bellied Glaſs, open a-top, and ending in a hollow Stem below; ſo that a Mixture of Oil and Water being pour'd into it, and ſuffer'd to reſt 'till they ſeparate, the Water may be ſeparated from the Oil.

g. Is the Droſs, Cruſt, or *Scoria*, found at the

the top of a melted Metal, or metallic Matte being often in the form of a vitrified Mafs, Glaſſy Subſtance, and proceeding from t Flux employed, and united with ſome ſto recrementitious Matter contain'd in the Or But when a large proportion of a ſaline Flux uſed, the Slag will relent, or even diſſolve the Air.

*Solvent.* *See* Menſtruum.

*Stum.* Is *Muſt*, clarified by ſtanding and racking then put up into matched Caſks, that is, Caſ impregnated with the Fume of burning Brim ſtone, ſo as to be preſerved ſound in an unfe mented State. *See* Muſt.

*Sublimation.* Is the raiſing of a dry Body by he into Flowers, or a ſolid Cake, at the top of t containing Veſſel; being a kind of Diſtillatic ſuited to dry Bodies.

*Subſidence.* Is the ſuffering a Liquor to ſettl and fine itſelf, by ſtanding.

*Sulphur.* Is another Name for Brimſtone; b in a more Technical Senſe, denotes the fa unctuous, or oily Principle in Bodies; or th part of them, which is truly inflammable.

*Thermometer.* Is an Inſtrument contrived to me ſure the Degrees of Heat. Thoſe made wi Spirit of Wine, ſerve for the leſſer Degree and thoſe with Oil, or Quickſilver, for t greater.

*Triture.* Is the grinding, or rubbing any ſol Body to Powder in a Mortar, or upon grinding, or levigating Stone.

*Torrefaction.* Is the roaſting, or ſcorching, o Body by the Fire, in order to diſcharge a pa either unneceſſary or hurtful, in another Op ration, as Sulphur is diſcharged from an Or before the Metal can be obtained to advantag

*Turn*

*Turnſol.* Is a red Colour prepar'd from the Juice of the Sun-Flower, and fermented Urine; which Colour being, in a fluid State, drank up in Linen Rags, and dried, is the thing ſold by the Dry-Salters to the Dyers and the Wine-Coopers, for dying Cloths, and tinging Wines Red.

*Vitrification.* Is the turning of a Body to Glaſs in the Fire.

*Waſh.* Is the ſame thing as fermented Wort, or any fermented Liquor, fitted to afford an inflammable Spirit, or Brandy, by Diſtillation.

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# ERRATA.

THE Author being at a distance from the Press, and not having the opportunity of revising the Sheets, many Errors have escaped the Corrector; the principal whereof the Reader is desired to rectify, as follows.

Page 18, Line 16, for *and acid*, read *acid*.
p. 23, l. 31. for *Compositions*, r. *Corpuscles*.
p. 33, l. 12. for *causes it*, r. *ceases*.
p. 51, l. 10. for *Oil*, r. *with Oil*.
p. 53, l. 3. for *constituted*, r. *confined*.
p. 70, l. 32. for *white or crystal Marble*, r. *white Marble, or Crystal*.
p. 80, l. 12. for *moving*, r. *moveable*.
p. 83, l. 2. dele *in Water*.
p. 89, l. 6. for *on*, r. *an*.
p. 104, l. 19. for *afterwards*, r. *now*.
p. 107, l. 6. after *dissolved*, add *therein*.
p. 108, l. 15. for *putrified*, r. *purified*.
p. 123, l. 6. for *Treacle-Wort*, r. *Treacle, or Wort*.
p. *126, l. 26. for *every*, r. *even*.
ibid. p. 30. after *Malt*, ins. *for it*.
p. *155, l. 16. for *as with*, r. *with*.
p. *156, l. 18. for *purified*, r. *putrified*.
p. *161, l. 30. dele *and*.
p. *170, l. 16. for *Sublimation*, r. *Fulmination*.
ibid. l. 36. for *Nitre*, r. *Tartar*.
p. *172, l. 10. dele *and*.
p. *176, l. 10. dele *not*.
p. *177, l. 18. after *Water*, insert *Salt and Oil*.
p. *182, l. 3. for *they*, r. *we*.
ibid. l. 23. for *reuniting*, r. *recruiting*.
p. (*194) for *true*, r. *due*.
p. (*204,) l. 24. for *an*, r. *our*.
p. (*209), l. 2. for *coloured*, r. *calcined*.
ibid. l. 18. for *fomented*, r. *fermented*.
p. (*211), l. 5. for *Rags*, r. *Bags*.
p. *206, l. 15. for *Chemist*, r. *Climate*.
p. *208, l. 13. after *this*, insert *kind*.
ibid. l. 35. for *close*, r. *cool*.
p. *209. l. 8. for *distributed*, r. *disturbed*.
ibid. l. 13. for *boiling or heat*, r. *or boiling heat*.
p. *212, l. 19. after *they*, insert *may*.
p. *213, l. 2. for *richness*, r. *smallness*.
p. *216, l. 17. f. *when*, r. *whilst*.
p. *220, l. 3. f. *compleat*, r. *complex*.
p. *221, l. 25. f. *cheaper*, r. *cleaner*.
p. 125, l. 3. for *but*, r. *where*.
p. 139, l. 8. f. *vegetable*, r. *volatile*.
p. 142, l. 2. for *than*, r. *than that*.
p. 144. l. 17. for *Deduction*, r. *Detection*.
p. 146, l. 9. for *Sect*, r. *Fact*.
ibid. l. 22. for *nauseous and*, r. *nauseous Smell*.
ibid. l. 25. f. *Effusion*, r. *Affusion*.
p. 148, l. 3. after *than*, ins. *that*.
ibid. l. 7. for *by the Mixture*, r. *the Mixture*.
p. 149, l. 6. for *a kind, thin, pappy*, r. *a kind of thin Paste, or pappy*.
ibid. l. 11. for *Stores*, r. *Pores*.
p. 150, l. 33. for *bad*, r. *best*.
p. 151, l. 11. f. *whereby*, r. *whence*.
p. 153, ult. after *soften*, dele *often*.
p. 154, l. 25. for *no less*, r. *no greater*.
p. 155, l. 30. for *Lixivia*, r. *Lixivium*.
p. 164, l. 20. dele *the*.
p. 168, l. 14. for *the denominated red Bodies*, r. *the Bodies denominated red*.
p. 170, l. 14. for *being not*, r. *or been*.
p. 171, l. 22. for *coloured*, r. *calcined*.
p. 178, l. 13. for *Solution, or*, r. *Solution of*.
p. 182, l. 29. f. *Archol*, r. *Archil*.
p. 188, l. 9. for *coloured*, r. *calcined*.
p. 193, l. 5. f. *artful*, r. *useful*.
ibid. l. 21, for *treated*, r. *traced*.
p. 201, l. 20. for *concretive*, r. *unactive*.
p. 204, l. 16. f. *consent*, r. *contact*.
p. 205, l. 24. for *lain that*, r. *lain here, that*.
p. 210, l. 14, 15. for *Diacodium*, r. *Diascordium*.
p. 211, l. 12. f. *Tartar*, r. *Mortar*.
p. 213, l. 17. for *Mililet-suet*, r. *Melilot-suet*.

p. 214, l. 12. after *Oils* inſ. *and.*
ibid, l. 29. for *in the Oil by boiling*, r. *by boiling in the Oil.*
p. 216, l. 2. f. *propoſed*, r. *prepared.*
p. 218, l. 27. f. *Bercardic Powder*, r. *Bezoardic Powder.*
p. 224, l. 2. for *the*, r. *tho'.*
p. 228, l. 8. in the margin, dele *Hiſtory of Drugs.*
p. 229, l. 13. for *Powder, Solution*, r. *Powder, or Solution.*
p. 233, l. 18. after *beat* inſert *in*, and dele *in* at the beginning of the next line.
ibid, ult. after *ſeem*, inſert *to be.*
p. 236, l. 9. for *in*, r. *and.*
ibid, l. 12. dele *ſuch.*
p. 241, l. 19. for *Succeſs at firſt*, r. *Succeſs as at firſt.*
ibid, l. 32. for *eight*, r. *eighty.*
p. 243, l. 27. for *Lead*, r. *Load.*
p. 247, l. 5. for *the Ore*, r. *if the Ore.*
p. 250, l. 22. in the margin dele *ſeverally.*
p. 252, l. 3. for *Infuſion*, r. *Fuſion.*
p. 254, l. 19. for *preſſes*, r. *paſſes.*
p. 257, l. 9. for *ſafe*, r. *ſoft.*
p. 258, l. 8. for *and Lead*, r. *of Lead.*
p. 268, l. 4. for *Sperth-ſtone*, r. *Spath-ſtone.*
p. 277, ult. for *introduce*, r. *to introduce.*
p. 284, l. 32. for *vitrify it*, r. *vitrify with it.*
p. 291, l. 22. for *Swark*, read *Schwartz.*
p. 294, l. 6. for *Flame*, r. *Fume.*
p. 296, l. 11, 12. for *Iron, Stone*, r. *Iron-ſtone.*
p. 310, l. 20. for *particularly*, r. *particular.*
p. 315, l. 14. for *expenſive*, r. *extenſive.*
p. 320, l. 32. after *ſo*, inſert *as.*
p. 321, l. 3. dele *procuring and.*
p. 330, l. 19. for *linger.* r. *long.*
p. 331, l. 9. for *up*, r. *of.*
ibid, l. 25. for *proceed*, r. *deſcend.*

The Running-Title of the firſt Lecture, viz. *Philoſophical Chemiſtry*, is, by an Overſight in the Printer, continued on from *page* 125 to 284, inſtead of the peculiar Titles of the ſeveral Lectures in thoſe Pages; thus the Running-Title from *page* 125 to 131, inſtead of *Philoſophical Chemiſtry*, ſhould be, *Of Diſtillation*; from *page* 135 to 163, *Of Oils and Salts*; from *page* 167 to 191, *Of Colours*; from *page* 193 to 217, *Of Common Pharmacy*; from *page* 219 to 237, *Of Simple Pharmacy*; from *page* 240 to 263, *Of Minerology*; and from *page* 265 to 283, *Of Metallurgy.* After which begins a freſh Miſtake in the paging; the Page immediately following *page* 284 being made 385, which Miſtake in the Hundred is continued on to the end of the Book.

# LECTURE I.

CONTAINING

I. *An Account of the Office, and Objects, of* Chemiſtry.

II. *The* Chemical *Treatment of Bodies.*

III. Rules *for making new Diſcoveries in the Art.*

1. THE Deſign of theſe Lectures is to enlarge the Bounds of Chemiſtry; by applying it to the Advancement of Natural Philoſophy, the Illuſtration and Improvement of the known Arts, and the Diſcovery of new ones. *The Deſign.*

2. In proſecuting this Deſign, we would ſpeak to the Eye rather than the Ear; or indeed to the Underſtanding rather than the Senſes; and by means of appoſite Experiments, ſcientifically explained, lead to the Diſcovery of *Phyſical Axioms*, and *Rules of Practice*, for producing uſeful Effects, in the way of a *Philoſophical Chemiſtry*. *The Manner of Execution.*

3. *Philoſophical Chemiſtry* we define, a rational Art of, (1.) dividing, or reſolving, all the Bodies within our power; (2.) by means of all the Inſtruments we can procure; (3.) as well into integrant as conſtituent Parts; and (4.) joining theſe Parts together again; (5.) ſo as to diſcover the Principles, Relations, and Changes, of Bodies; (6.) make various Reſolutions, Mixtures and Compoſitions; (7.) find out the phyſical Cauſes of phyſical Effects; and (8.) hence improve the State of natural Knowledge, and the Arts thereon depending. *Philoſophical Chemiſtry defined.*

*The Business of the Lectures.*

4. To explain this Definition, in a concise general manner, is the business of our first *Lecture*; and to illustrate it fully, will be the Business of all the rest.

5. Our Definition consists of eight Parts; the first whereof regards the *Objects of Chemistry*.

*The Objects of Chemistry.*

(1.) These *Objects* are all the Bodies within our Power. We should therefore, if it were practicable, take a particular View of the Contents of the terraqueous Globe. To abridge the Labour, we shall single out the more capital and useful Sorts; and range them in some Order, by way of Specimen, or Sample, of that grand Repository of infinite Materials *.

*Classed.*

*The Objects of Chemistry, classed.*

The Productions of the Earth are divided into,

I. *Minerals.* II. *Vegetables*, and III. *Animals.*

*Class* I.

I. Minerals are subdivided into (1.) Metals and their Ores, (2.) Salts, (3.) Sulphurs, (4.) Stones, (5.) Earths, and (6.) Semimetals.

The METALS are

*Gold*,
*Quicksilver*,
*Lead*,
*Silver*,
*Copper*,
*Iron*,
*Tin*.

} Ranged according to their specific Gravities, and compared with their Ores respectively.

II. SALTS. *Alum*,
*Artificial Salt*,
*Bay-Salt*,
*Borax*,
*Nitre*,
*Rock Salt*, or *Sal-Gem*,
*Sal Ammoniac*.

III.

* In the Course, a Set of Specimens was exhibited, in conformity with the following Catalogue.

III. SULPHURS. *Amber*,
*Arsenic, white, yellow, and red*;
*Auripigmentum*,
*Bitumen*,
*Brimstone, Common*,
——— *Native*;
*Coal*,
*Jet*,
*Petreol.*

IV. TRANSPARENT STONES.
From the *Diamond* to *Crystal.* } Ranged according to their Hardness, which is their Criterion, as Gravity is of Metals.

V. OPAKE STONES. *Alabaster*,
*Amianthus*,
*Emery*,
*Flint*,
*Hæmatites*,
*Loadstone*,
*Marble, and Porphire*;
*Lapis Calaminaris*;
*Talc*,
*Tripoli*, &c.

VI. EARTHS. *Bole*
*Chalk*,
*Marl*,
*Ore*,
*Ocre*;
*Ruddle*,
*Terra Lemnia*, &c.

VII. SEMIMETALS.
The Vitriolic.
*Vitriol*, green and blue, *viz.* of Iron and Copper;
*White Vitriol*, with other foreign kinds.

VIII. The Sulphureous SEMIMETALS.
*Antimony*,
*Bismuth*,

*Cinnabar, native,*
*Mundick,*
*Pyrites,*
*Zinck,* &c.

II. VEGETABLES are divided into

*Herbs, Berries, Flowers, Fruits, Grain, Seeds, Roots, Barks, Woods, Juices and Excreſcences.*

*Claſs* I. HERBS. *Angelica, Baulm, Hyſſop, Roſemary, Lavender, Sage, Tanſy, Thyme, Wormwood,* &c.

II. BERRIES. *Bay-Berries, Coffee, Kermes, Juniper,* &c.

III. FLOWERS. *Jaſmin, Saffron, Lillies, Marigolds, Roſes, Elder-Flowers, Violets, Flowers of Broom, Holly-Oak,* &c.

IV. FRUITS. *Cocoa-Nuts, Nutmeg, Jamaica-Pepper, Long-Pepper, Tamarinds, Caſſia Fiſtularis, Pomegranate,* &c.

V. GRAIN. *Rice, Indian Wheat, Sago, Millet,* &c.

VI. SEEDS. *Beech-maſt, Cardamom,* Gran. Paradiſ. *Muſtard-Seed, Sun-flower Seed,* &c.

VII. ROOTS. *Alkanet, Galangal, Gentian, Liquorice, Madder, Orris, Turmerick,* &c.

VIII. BARKS. *Caſſia, Cinnamon, Clove-Bark,* Cortex Peruv. *Mace, Oak-Bark, Winter's Bark,* &c.

IX. WOODS. *Cedar, Guaiacum, Logwood, Rhodium, Saunders,* &c.

X. JUICES are ſubdivided into natural and artificial, or into *Tears* and *inſpiſſated Juices.*

*Tears,* or natural Juices, of the Sycamor, the Birch, &c.

*In-*

*Inſpiſſated Juices* are divided into (1.) *Gums*, (2.) *Balſams*, (3.) *Roſins*, and (4.) *Sugars*.

(1.) GUMS. *Aloes*, *Gum Arabic*, *Aſſa Fœtida*, *Ammoniacum*, *Benjamin*, *Bdellium*, *Galbanum*, *Gamboge*, *Maſtich*, *Myrrh*, *Gum Elemi*, *Opopanax*, *Gum Sandarac*, *Gum Lac*, *Gum Tragacanth*, &c.

XI. (2.) BALSAMS. *Balſam Capivi*, *Opobalſamum*, *Balſam* Peru, Tolu, *&c.* The *Turpentines*. *Wax*, &c.

XII. (3.) ROSINS. *Camphire*, *Frankincenſe*, *Roſin of Guaiacum*, *Roſin of Jalap*, *Scammony*, *Burgundy Pitch*, *Common Roſin*, Sang. Draconis, *&c.*

XIII. (4.) SUGARS. *Honey*, *Manna*, *Sugar*, &c.

XIV. EXCRESCENCES. *Jews Ears*, *Agarick*, *Miſletoe*, the *Moſſes*, *Galls*, &c.

III. ANIMALS.

*Claſs* I. ENTIRE ANIMALS. *Ants*, *Bees*, *Cantharides*, *Cochineal*, *Millepedes*, *Vipers*, &c.

II. THEIR SOLID PARTS. *Bone*, *Hart's-horn*, *Ivory*, *Cuttle Bone*, *Elk's Hoof*, *Human Skull*, *Caſtor*, &c.

III. CONCRETED ANIMAL JUICES. *Goat's Blood*, *human Blood dryed*, *Lard*, *Marrow*, *Sperma Ceti*, &c.

IV. EXCREMENTS. *Album Græcum*, *Civet*, *Musk*, *Pigeon's Dung*, *Silk*, &c.

6. *Bodies* have been uſually conſidered under three general Claſſes, called by the Names of the Vegetable, Animal and Mineral *Kingdoms*. This Diviſion is, perhaps, too ſcanty; as excluding many Particulars of the marine and atmoſpherical Regions: In the Sea are found Coral, Shells, Spunge, Bitumen, Ambergreaſe, Mixtures of

*Bodies how to be divided.*

Salt, Slime, Fæculencies and the corrupted Parts of Fiſh, &c. which may poſſibly be irreducible to any of the three Kingdoms. And the Atmoſphere abounds with Air, Light, Water, Meteors, Exhalations and Effluvia of the Earth, differently combined; ſo as not to appear either of a direct Vegetable, Animal or Mineral Nature.

7. The *Objects of Chemiſtry*, therefore, are taken from the three larger Maſſes, or Regions, of the Globe; *viz.* the *Earth*, *Water*, and *Atmoſphere*.

*The general Structure of the Earth.*

8. Our Knowledge of the *Earth* reaches but little below its Surface. So far as Men have dug, it appears a Compages of numerous ſolid Subſtances, ranged in a diſorderly manner; which may be phyſically neceſſary, to afford different Partitions, or Beds, of Soil, Gravel, Clay, Stone, Coal, Marcaſites, Ores, Gems, &c. each ſerving as a Matrix to the other.

*Earth in particular.*

9. By *Earth* is commonly meant the Soil, Mould, or Coat, wherein Vegetables grow. This Coat, which reaches but a little depth, is the direct and immediate Seat of Vegetation. And with this Earth we chuſe to begin our Experiments; propoſing (1.) A general Analyſis of Garden Mould; (2.) The Preparation of a general kind of Flux, for the aſſaying of Ores. (3.) The general Method of aſſaying Ores for their Metal. (4.) A general Analyſis of common Water. (5.) A general Analyſis of the Air. (6.) A general Example of the Method of reducing Bodies to their integrant Parts. (7.) A general Example of reſolving Bodies into their conſtituent Parts; and (8.) An Example of Reduction, or the Method of recompoſing, or recovering, Bodies after Solution.

## II.

### Experiment I.

*The Analyſis of Garden Mould, begun.*

10. We took two Pounds of freſh, black and rich Garden Mould, and ſtirred it well in two Quarts of fair Water, gently warmed; then letting the groſſer Part ſettle to the Bottom, we filtred the Liquor thro' Cap-Paper; and found that it paſſed conſiderably muddy, or impregnated with the finer Parts of the Earth; which it wou'd not eaſily depoſite upon many Days ſtanding in a quiet Place *. *Earth analyſed.*

11. The Deſign of the Experiment is to obtain a proper Liquor for diſcovering the Matter which the Earth affords to Plants in Vegetation, or the natural Juices, and natural Salts, of Garden Mould; becauſe nothing ſeems capable of riſing in Vegetation, but what is ſoluble in moderately warm Water, and will paſs the Pores of Paper, ſomewhat in the ſame manner as it does the natural abſorbing Veſſels, or Strainers, of a Plant. Whence the filtred Liquor of our Experiment may be examined by chemical Treatment; as by Evaporation, or the way of trying *Mineral Waters*, &c. as we ſhall ſee hereafter in our fourth Lecture.

12. Ores are the next uſeful Species of *Earth*; the general Treatment whereof, for obtaining their Metal, depends upon the Uſe of the *Black Flux*.



* See this Experiment carried a greater length in *Lect.* IV. Exp. I. and II.

## EXPERIMENT II.

*The Method of making the Black Flux, for the aſſaying of Ores.*

*The Black Flux.*

13. We took one part Nitre, and two parts common Tartar; and reducing each to Powder, we mixed them together, and deflagrated the whole in a Crucible, by lighting the Mixture a-top; which thus turns to a kind of *Alkaline Coal*, that is to be pulverized, and kept in a cloſe Glaſs, to prevent its diſſolving, as it would do in a moiſt Air.

14. This Flux is of general uſe; and to have it ready at hand, ſhortens the Buſineſs of making Aſſays in Metallurgy; and renders the Operation more exact, than when crude Tartar and Nitre are employed; becauſe the Deflagration might thus carry off ſome part of the Ore, and defraud the Account. For the ſame Reaſon, the Mixture is here directed to be fired a-top; otherwiſe a conſiderable Part might be loſt in the Deflagration; which would prove much more tumultuous and violent if the Matter was thrown into a red-hot Crucible.

## EXPERIMENT III.

*The general Method of analyſing Ores.*

*Ores analyſed.*

15. We took two Ounces of Copper Ore reduced to Powder, and mix'd it, in a Mortar, with twice its Weight of the black Flux; then, in a Wind-Furnace, fuſed it briſk, that it might run thin for about four Minutes: when ſuffering the Crucible to cool, we broke it, beat off the Slag, and weigh'd the Metal.

16. This Experiment ſhews the Method of treating any unknown Ore, to diſcover, in the way

way of Aſſay, or Proof, the Kind and Proportion of Metal it contains.

17. The *Cauſe* of the Effect depends upon a Separation of the terreſtrial, ſulphureous, or other heterogeneous Parts of the Ore, which are either here vitrified, or otherwiſe detained by the Flux; whoſe Property it is to vitrify Earth in the Fire, and ſtrongly join with Sulphur; at the ſame time that it does not alter the Metal, but leaves it to its own nature; whence, by its ſuperior Gravity, it ſinks pure to the bottom of the Crucible; as being now made fluid, and ſet free by Heat and thin Fuſion, from the heterogeneous Parts before mixed in among it *. *The Rationale of the Proceſs.*

18. WATER is generally divided into ſalt and freſh; with regard to the Ocean and Rivers. But it ſeems diviſible into as many different Species, as the Earth is into Beds. Thus there are Mineral Waters of various kinds, according to the Mineral Subſtance they run over, and become impregnated with: tho' this Impregnation ſometimes happens in the way of Vapour, or Exhalation. Water, therefore, in the general, may be as mixed a Body, as Earth in the general; and perhaps neither of them naturally exiſts in any conſiderable Purity †. *Water divided.*

## EXPERIMENT IV.

### *A general Analyſis of common Water.*

19. (1.) We found that common warm Water throws up numerous Bubbles, and explodes, in the exhauſted Receiver of the Air-Pump; and therefore contains what may, by way of diſtinction, be called Æther or Spirit. *Water analyſed.*

(2.)

---

* See the Lect. on Metallurgy.

† See *Lect.* V.

(2.) It contains a merely aqueous part; distinct from Æther, and the Sediment; as appears from distilled common Water.

(3.) It contains a dry solid Matter, which is either Earthy or Saline, as appears upon a full Evaporation; and from the Insides of Tea-Kettles, which, after long Use, are lined with a stony Matter, that beats off in Flakes, or crusty Pieces.

20. That Water is accounted best and wholesomest, which is lightest, most spirituous, and freest from earthy Sediment; and these Properties are usually found in pure Rain Water: this being naturally distilled from the Ocean, and Rivers; or by the Sun's Heat raised up into the Atmosphere; from whence it is returned, much after the manner of common Distillation *.

*The Atmosphere divided.*

21. The Atmosphere is a kind of dry Fluid, no less essential to the Earth than the moist one. It seems as heterogeneous as the Earth or Water; tho' more rarified. It is dissimilar in its Parts; like the Body of the Earth; and has something analogous to Beds, or particular Portions abounding with different kinds of Effluvia, according to the Difference of the Countries, and Places, over which it extends. Thus over Mount *Ætna*, or other *Vulcano's*, it must necessarily be impregnated, after the manner of certain Mineral Waters, with the Fumes of burning Minerals; over the Island *Ceylon*, with Aromatic Effluvia; over *London* with the Smoke of Sea-Coal, *&c* †.

## EXPERIMENT V.

### *A general Analysis of the Air begun.*

*The Air analysed.*

22. A proper Analysis of the Air, or any integrant part of the Atmosphere, has scarce hitherto been attempted. (1.)

* See *Lect.* V.

† See *Lect.* III.

(1.) That it is an elastic Fluid appears by its distending Bladders, and breaking Glasses, in the exhausted Receiver of the Air-Pump. (2.) That it is essential to Life, appears by Animals dying without it. (3.) That it may receive invisible Influences, or Alterations, as well as visible Effluvia, appears from its becoming poisonous by passing thro' Fire; and by containing gross Smoak, and the fine Particles of fermenting or putrefying Bodies: And (4.) that it is naturally a Compound, appears by the Water it deposits in dry Salt of Tartar; and by changing the Colours of various Bodies, *&c.*

23. We shall hereafter attempt a more particular Analysis of the *Atmosphere*, in order to a Choice of the best Places for Health, Habitation, and the Exercise of particular Arts; on account of certain Properties in certain Places, arising from the different Mixtures, or Compositions, of the Air in different Parts *,

24. The *Instruments of Chemistry* are all those we can any way procure †. There are several Instruments continually at work, in the three larger Masses, or Kingdoms, of the Globe, *viz.* The Earth, Water, and Atmosphere, for the immediate Production of Effects. We evidently find, that Metals and Minerals are formed within the Earth; Vegetables on its Surface, shooting into the Air; Meteors in the Atmosphere; and Men, Beasts and Birds in the Confines of the two: The *Physical Causes* of all which are to be diligently sought; as so many *Rules of Practice.* *The Instruments of Chemistry.*

25. The principal physical Agents in Nature appear to be, (1.) Heat. (2.) Cold. (3.) Air, or the integrant Parts of the Atmosphere. (4.) Water. And (5.) proper Beds, or *Matrices.* This is Matter *The physical Agents of Nature.*

* See *Lect.* III.

† See above §. 3.

Matter of direct Obſervation; and might o caſion the eſtabliſhing of the four common El ments, Fire, Air, Water and Earth.

*The Sun.* 26. (1.) The *Sun* is the principal Source of He upon the Earth's Surface, and the Confines of t Earth and Atmoſphere. Without this, all t Bodies upon our Globe would doubtleſs grow gid, lifeleſs and fixed. 'Tis this that ſtirs with them, as the main Spring of their Actions. Hen Vegetation, and Animalization, are evidently pr moted; and hence the Ocean and the Atmoſphe continue in a fluid State *.

*Cold.* 27. (2.) *Cold* is correlative to Heat; and th perhaps no more than a leſs Degree, or Abſenc thereof, yet has, in the natural State of thing an inſtrumental Efficacy; as in the condenſi of Solids †, the coagulating of Fluids ‡, the parating of Salts ‖, Spirits **, *&c.* And by mea of Cold and Heat, uſed alternately, it ſhou ſeem that ſome capital Operations of Nature a performed; eſpecially in the vegetable Kingdo by the Reciprocation of Day and Night, Sumn and Winter ††.

*Air.* 28. (3.) Air, or any integrant Part of the Atm ſphere, is an Elaſtick Fluid, that expands w Heat, and contracts with Cold; ſo as apparen to generate Motion, and produce Effects. It a mates Fire; and has a great Influence upon the L of Animals: it alſo mixes in among, and uni itſelf with, Bodies; ſo as to conſtitute a mater Part thereof ‖‖. It is the great Receptacle of I flu

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* See *Lect.* II. *paſſim.*

† Which are rarified by Heat, but contracted by Cold.

‡ As aqueous Liquors into Ice.

‖ As Salt is ſeparated in the Freezing of Salt-Water.

** As Spirit is ſeparated in the Freezing of Wine, urin Spirits, and diſtilled Vinegar.

†† See *Lect.* III.

‖‖ See *Lect.* III.

fluvia from the Earth; the Matrix of Meteors, the continual Support of Birds, Beaſts, Plants and Men, and in ſome degree nutrimental *.

29. (4.) *Water* is not only contained in the Earth, as in a Reſervoir, but likewiſe floats in the Atmoſphere. In both Caſes it is actuated, rarified and put in motion by Heat; ſo as to prove inſtrumental in producing Effects. Thus it produces Clouds, Rains, Dews, Springs and Rivers. It refreſhes the Earth, recruits Vegetables; and is the Support of Fiſh and other Animals, by conveying Nutriment to all their Parts. 'Tis alſo the firſt and immediate Inſtrument of Fermentation, Putrefaction, Corruption, and Change, in all vegetable and animal Subjects †. *Water.*

30. (5.) Proper Beds, or *Matrices*, alſo appear to have an inſtrumental Agency in the Production of natural Bodies. Every Subject of an Operation is neceſſarily contained in ſomething that may (1.) afford it a Lodgement, (2.) make ſome Reſiſtance, and (3.) convey Heat, Cold, Water, or Air, to it, or determine their Actions upon it. Thus in Vegetation, the Matrix Earth ſupports the Seed, reſiſts its Swelling, and conveys a ſtrained, or prepared, Moiſture to it. The *Matrices* of Gems and Ores not only afford a proper Lodgement to the Subject-Matter, but alſo reſiſt its Growth, by the Preſſure of their Sides; which, however, give way a little, and at the ſame time ſtrain, and convey ſuitable Juices to the Subject. And ſomething of this kind is obſerved of the *Fœtus in Utero*, the Hatching of Eggs, *&c.* inſomuch that Cloſeneſs, moderate Reſiſtance, or a ſlow yielding of the Sides of the Matrix, and a ſtraining of the Juices through them (unleſs ſupplied *Matrices.*

* As it adds to the Subſtance of Vegetables and Animals. See Mr. *Hale's Vegetable Staticks*, and hereafter *Lect.* III.

† See *Lect.* VII. and XII.

plied from within) ſeem requiſite for the Formatio and Production of all Vegetable, Animal, an Mineral Subſtances. Whence we are furniſhe with a capital Rule for the Improvement of Che miſtry, natural Philoſophy, and Arts; and taugh that, in order to imitate Nature, Chemiſtry muſ not be confined to the ſole Uſe of Fire, as its In ſtrument, but occaſionally employ Water, Cold Air, Earth, and proper *Matrices*, or Veſſels.

*Artificial Inſtruments of Chemiſtry.*

31. But beſides theſe *natural Inſtruments*, there is a great Variety of artificial ones, belonging to Chemiſtry; which ſeem to raiſe the Power o this Art, in ſome reſpects, above the Power of Na ture: thus, by means of particular Menſtruums it performs Operations which Nature of herſel does not. For inſtance, of all the Metals, only Iron and Copper are found naturally converted into Vitriol; whereas Chemiſtry makes Vitriols even of Gold, Silver, Tin and Lead. And hence the Productions of Art may be much more numerous, than the Productions of Nature; or enlarged at pleaſure, to the great Enrichment of Arts, and the Enlargement of the Kingdom of Man *.

*Veſſels, Furnaces, Utenſils.*

32. Another Set of Inſtruments belonging to Chemiſtry are *Veſſels*, *Furnaces*, and *Utenſils*; of which there is a great Variety, for various Purpoſes, and capable of producing numerous Changes in Bodies; as by Amalgamation, Cementation, Fuſion, Fermentation, Putrefaction, Reduction, &c.

*A new Set.*

33. We add to the above-mentioned a new Set, *viz.* The *Air-Pump*, the *Condenſer*, *Digeſtor*, *Microſcopes*, *Burning-Concaves*, *Priſms*, *Lens's*, *Portable Furnaces*, and every other Inſtrument that can be invented, or procured, of advantage to the Art. 34.

* In which Light the numerous Productions of the Chemical Trades, may be conſider'd; as by Fermentation, Diſtillation, Dying, Soap-making, the Art of Glaſs, Metallurgy, &c.

34. There are two capital Ways wherein Chemistry divides its Objects, by the several Instruments above-mentioned; *viz.* into *integrant Parts*, and into constituent Parts. By integrant Parts we understand similar Parts, or Parts of the same nature with the Whole; as Filings of Iron have the same Nature and Properties as Bars of Iron. Under this general Operation, fall those particular ones of Triture, Limation, Solution, Amalgamation, Sublimation, *&c.* And by *constituent Parts*, we mean dissimilar Parts, or Parts of a different Nature from the Whole; as when artificial Cinnabar is divided into the Quicksilver and Sulphur: and under this general Operation come all kinds of Analyses or Resolutions. *Two principal kinds of chemical Division.*

## Experiment VI.

*A general Example of reducing Bodies into their integrant Parts.*

35. We took an Ounce of Quicksilver in a small Glass, and poured upon it two Ounces of *Aqua fortis*; then set the Glass in a Sand-Heat to warm: red Fumes soon appeared; and the Mercury, or Quicksilver, disappeared. We added a little more Mercury, 'till a small Particle was left undissolved at the Bottom, that the Solution might be saturated. Then decanted the clear Liquor: of which if a Drop be now viewed in a Microscope, no Particles of the Mercury appear separate. *Quicksilver rendered invisible by a minute Division into integrant Parts.*

36. Here we find the opake and heavy Body of Mercury transparently dissolved, and equally diffused in a Fluid, at least ten times lighter than itself; whilst the Mercury still remains unaltered; and recoverable in its pristine Form, barely by Collection or Aggregation, as we shall presently see *; so that it is thus only divided into homogeneous

* Under Experiment VIII.

geneous or integrant Particles, and not ſeparated into Particles of different Kinds.

## EXPERIMENT VII.

*A general Example of reſolving Bodies into their conſtituent Parts.*

*Brandy reſolved into its conſtituent Parts.*

37. We gently diſtilled two Gallons of common *Brandy* by the *Balneum Mariæ*, which reſolved it into Spirit of Wine and Water. For the Spirit of Wine, being the lighteſt Part, comes over firſt, and leaves a large Proportion, or about one half, of Water, or Phlegm, behind in the Still.

38. And thus Brandy is ſeparated into the two very different or heterogeneous Parts, whereof it conſiſts. And hence, by the way, all Rums and Brandies contain one half Water, no way eſſential to them, that might commodiouſly be left behind upon their Tranſportation and Carriage. And this holds ſtill ſtronger of Arracks, which uſually contain three fourths Water, to one of Spirit *.

*Aggregates and Mixts what.*

39. Theſe two general Operations of Chemiſtry bear relation to two general Structures of Bodies, *viz.* the *Aggregate* and the *Mixt*. Aggregates in their Reſolution conſtantly retain their Mixture, in every the ſmalleſt Part, or Atom; but when Mixts are reſolved, the Mixture is deſtroyed, and two or more new Aggregates are produced: thus when Brandy is reſolved, Spirit of Wine, or *Alcohol*, and *Water* are produced.

*Senſible Bodies compoſed of inſenſible.*

40. Every ſenſible Mixt, or Aggregate, is compoſed of many inſenſible ones. Before Gold can become ſenſible to us, there muſt be a Collection of numerous Parts, that are ſeparately inſenſible; tho' all of them perfect Gold. The minuteſt

* See *Lect.* VII. Exp. IV. and *Lect.* XII. Exp. IV.

minuteſt Grain of Cinnabar has two different Parts, Sulphur and Quickſilver. The minuteſt Grain of Glaſs contains Sand and fix'd Salt. And ſo when Quickſilver is diſſolved in *Aqua Fortis*, the leaſt aſſignable Portion of the Menſtruum contains a proportionable Quantity of Mercury to the whole.

41. (4.) Either the integrant, or the conſtituent Parts of Bodies being once divided or reſolved *, various Occaſions in Chemiſtry require them to be joined together again, for compoſing a Whole, like the original Subject. This Operation is the Converſe of the former. Thus by ſimple Mixture we recompoſe Brandy from *Alcohol* and Water; and by Precipitation with a Copper-Plate, collect the Quickſilver diſperſed in *Aqua Fortis*. *Recompoſition illuſtrated.*

## Experiment VIII.

### *An Example of the Method of recovering Bodies after Solution.*

42. Dilute part of the former Solution of Quickſilver with twice its quantity of fair Water; ſuſpend a Plate of Copper in the Liquor, and the Quickſilver will be ſoon recovered, and fall in its natural Form and Appearance to the bottom of the containing Glaſs; and being now taken, well waſhed, and dried, it is abſolutely indiſtinguiſhable from other Quickſilver that has not been ſo diſſolved. The Effect is owing to this, that *Aqua Fortis* diſſolves Copper eaſier than it does Quickſilver; ſo that it lets the Quickſilver fall in proportion, as it diſſolves the Copper. And this, by the way, is a general Example of *Precipitation*. *Quickſilver recovered.*



* See above, §. 3.

*The Principles, Relations and Changes of Bodies, how discoverable.*

43. (5.) To discover the Principles, Relations, and Changes of Bodies * produced in the Operations of Philosophical Chemistry; we must use all our Senses, assisted by proper Sets of particular Experiments, or new Ways of Examination: Otherwise we shall understand but little of the Powers of Nature and Art. Thus in the Experiment of Quicksilver dissolved in *Aqua Fortis*, we find by a slight Expedient, *viz.* by putting a piece of Copper into the Solution, that the Quicksilver, tho' rendred invisible, is not destroyed; but thus recovered in its pristine Form and Properties.

44. And thus, by casual Experiment, *Glauber* discovered his Way of preparing mineral and acid Spirits by means of Oil of Vitriol: for having once obtained this Oil, by an Analysis of Vitriol, he applied it to the Mineral Salts, and found it thus raised their volatile Acids in Fumes; which being augmented by Heat, and collected, are the acid Spirits, so useful in the whole Affair of Metallurgy, Refining, Dying, and many other Arts. And thus one new chemical Production may give occasion to many new Arts and Discoveries.

*The Resolutions and Mixtures of Chemistry.*

45. (6.) The Resolutions, Mixtures, and Compositions made by Chemistry †, are extremely numerous; and may be increased *ad infinitum*. We exhibited an Instance of Resolution in the Analysis of Brandy. And to this Class of Resolutions are referable all kinds of Depurations, Purifications, Separations, Clarifications, *&c.*

*The Productions of Mixture.*

46. By Mixture we produce all the artificial Vitriols, Soaps, Glasses, *&c.* and can compound these again in an almost infinite Variety. So that of the Resolutions, Mixtures, Compositions and Recompositions in Chemistry, there seem to be no

* See above § 3.

† Ibid.

no Bounds; whence great room is left for the making of new chemical Discoveries.

47. (7.) Whilst we carefully attend to the several Steps of chemical Operations, we are led into some kind of Knowledge of the *Physical* or *Material Causes* of the Effects * produced, as may appear from our Endeavour to assign the chemical *Causes* in the foregoing Experiments. And the greater Attention and Diligence we employ, the juster Notions we shall have, or the nearer Approximation we shall make to the Discovery of these Causes; which being once certainly found, they afford *Rules of Practice*, to be occasionally employed for producing the same Effects again. For to discover the Cause of an Effect, is to discover a Rule for producing that Effect. *The Physical Causes of chemical Effects.*

48. (8.) The Improvement of natural Knowledge, Chemistry itself, and the Arts thereon depending †, are the Consequence of a due Prosecution, and Improvement of *Philosophical Chemistry*; which, for distinctness sake, we shall hereafter consider, as it more immediately relates to (1.) *Fire*, (2.) *Air*, (3.) *Earth*, (4.) *Water*, (5.) *Menstruums*, (6.) *Fermentation*, and *Putrefaction*, (7.) *The Analysis of Bodies*, (8.) *The Synthesis of Bodies*, (9.) *Vegetable Curation*, (10.) *Vinous* and *acetous Fermentation*, (11.) *Distillation*, (12.) the making of *Oils*, (13.) *Salts*, (14.) *Colours*, *Dyes* and *Stains*, (15.) *Pharmacy* and *Medicine*, (16.) *Minerology*, (17.) *Metallurgy*, (18.) *Pyrotechny*, and (19.) the farther *Uses of Chemistry*: so as to shew what has already been done on these Subjects, carry the View somewhat further, and recommend a fuller Prosecution to others. *The Advantages of improving Chemistry.* *The Subjects to be treated in the following Lectures.*



* See above §. 3.
† Ibid.

*Three general Rules for conducting Philosophical Chemistry.*

49. 'Twas said in our Definition *, that Philosophical Chemistry is a *rational Art*; by which we mean it may be conducted by Rule, and need not be left to accidental Tryal, and casual Experiment. The Rules for duly conducting the Art, we would endeavour to comprize under the following three.

## III.

## RULE I.

50. *When a Body is offered, in order to have new Properties discovered in it, different from those general ones of Figure, Gravity, Elasticity, &c. which come under Mathematical Consideration, let the Body be resolved, by degrees, into the simplest constituent Parts, it is any way capable of, by the Instruments above described. And let Trial be made with each separate part on a variety of Bodies, according to some Analogy of a previous Chemical Knowledge; leading from one thing to another, in a sure or probable Method of Ratiocination.*

## RULE II.

51. *Let the several parts, obtained by the preceding Analysis, be reunited, beginning with two, and proceeding gradually to the whole Number; using at first the gentlest Degree, then the intermediate, and at last the highest Degrees of Heat and Cold. Thus, for example, join the fixed Salt and Oil of a Plant together, first by simple Digestion, and afterwards by boiling; which affords a third Production dissimilar to all the rest, and known by the Name of* Soap. *So again melt the same fixed Salt with the Earth of the Plant; and this will afford*

* See above §. 3.

*ford Glaſs. Let the laſt Attempt be to reunite all the ſeparated Parts of the Body; in order, if poſſible, to form the original Subſtance again.*

## Rule III.

52. *In every Operation performed, let the greateſt Diligence and Exactneſs of Obſervation be uſed, with regard to all the principal Phænomena and Effects produced; let theſe Phænomena be duly regiſtred, tabled, conſidered, and compared together, after the ſtrict Geometrical Manner; the Reſult whereof, if here be no conſiderable Errors committed, will lead o a Knowledge of the ſecret Springs, Motions, Inſtruments, and Means made uſe of by Nature for roducing Effects. And thus with the proper Care nd Application, juſt* Canons, *or Rules of Practice ay be formed.*

53. The Art of Chemiſtry having been little ultivated in this view; all that we can at preent do, is to make ſome firſt Offers or Attempts owards forming ſuch *Canons* or *Axioms*; which e conſign over to further Experience and Obervation, to be *verified*, *amended*, or *rejected*. ut if a competent number of juſt *Axioms* and *anons* might in this manner be formed; others f a higher nature might be raiſed from them; as that, at length, Practice and Experience ould lead to a true Theory or Speculation; and heory, back again to a more extenſive and uſeI Practice, to the great Improvement of Phiſophy, and Benefit of Life.

IMPERFECT AXIOMS, or CANONS deduced from the preceding Enquiry, for directing farther Discoveries and Improvements in chemical and natural Knowledge.

54. (1.) *We may learn from our present Enquiry, that a true Chemistry (as it may perhaps be justly called) is exercised by Nature in the Vegetable, Animal, Mineral, Marine, and Atmospherical Regions; and that by it all Bodies are produced, converted, renovated, repaired, and maintained: and that in the exact Discovery, Imitation, and Controul, of this* natural Chemistry, *consists the Perfection of the* artificial *.

(2.) *That neither the Eye, nor all the Senses together, can give us any Information of the latent Properties of Bodies, their Natures and Uses: but only particular Tryals and Experiments, well attended to and considered* †.

(3.) *That Experiments are but a kind of dead things, unless they have a direct Use in Life, or tend to the raising of* Axioms *and* Canons, *for improving our Knowledge, and extending our Power over the Works of Nature* ‖.

(4.) *That he who can chuse fit Subjects, and place them in proper* Matrices, *or including Vessels, supply them duly with Air and Water, Heat and Cold, may probably produce great Effects in Imitation of Nature.* **

(5.) *That Nature points out three ways of producing Physical Effects, different in Fineness,* viz. *In Beds of Earth, Beds of Water, and Beds of Atmosphere: Beds of Earth for Minerals, of Water for Fish, and of the Atmosphere for Birds, Meteors,*

* See above, §. 7, 8, 9, 21, 24, 25.
† See above §. 35, 36, 38, 39, 41.
‖ *Passim*
** See §. 24, 25, 26, 27.

*teors*, &c. *The Confines of the two for Plants and Animals; and a rarified Mixture of all Matters for Meteors* *.

(6.) *That Men may make use of the same Instruments as Nature does*, viz. *Fire, Air, Water, and Earth, and consequently produce the same kind of Effects, if Skill, that is, Knowledge, be not wanting. Whence to improve in Knowledge, is to improve in Arts* †.

(7.) *That Chemistry is not confined to the Use of Fire only; but, in imitation of Nature, may employ Cold, Air, Water, and Earth upon Matter, in various Degrees of Simplicity, Combination, and Mixture; which shews an extensive Method of enlarging the Bounds of the Art* ‡.

(8.) *That Fire is not only an Analysis in some Cases, but also a Mixer of Bodies in others; and this to the advantage of Chemistry: For if it only separated, it could produce but few Effects, in comparison of that infinite Variety it now produces, both by Mixture and Separation* ‖.

(9.) *That it might be proper to try the Reciprocation of Heat and Cold in Chemical Operations, after the manner of Nature, in Day and Night, Summer and Winter* **.

(10.) *That Body, in all its Forms, is the Object of Chemistry; not considered mathematically, nor mechanically, but operatively and effectively* ††.

(11.) *That the Atoms, or primary small Compositions of Bodies, are insensible to us: Thus the first Particles of Gold, Salts, Metals and Minerals may float in the Air, and not be perceived by us,*



* See §. 25.
† See §. 25, 26, 27.
‡ Ibid.
‖ See §. 28—45.
** See §. 25.
†† See §. 3, 5, 7, 49. *& alibi passim.*

*'till they aggregate, or collect together; and make a ſenſible Maſs, or produce a ſenſible Effect* *.

(12.) *That ſome Operation of the Mind is requiſite to digeſt, methodize, and regiſter Chemical Experiments, and Obſervations; without which we cannot underſtand the Laws obſerved by Nature in Phyſical Operations; nor be able to imitate them: The Chemiſtry, or regular Proceſſes of the Mind, being here as neceſſary, as the Corporeal Operations themſelves* †‖.

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* See §. 35, 36, 38, 39, 41.

† See §. 3, 48, 49, 50, 51.

‖ More *Canons* and *Axioms* might be drawn both from the preſent *Lecture*, and all the following; but the Deſign of drawing them at all, is rather to recommend the Method than the Matters brought a ſecond time under conſideration.

# LECTURE II.

CONTAINING,

I. *The Nature, Properties, Office, and Uſe of* Fire *in general.*

II. *The Nature of Celeſtial, Subterraneous, and Culinary* Fire.

III. *The Effects of* Fire *on the Atmoſphere, and Bodies of the terreſtrial Globe.*

IV. *The Degrees of Heat regulated.*

## I.

*The preſent Deſign.*

1. OUR preſent Deſign is to ſearch into the Nature of Fire: This we ſhall attempt by means of Experiments, conducted after the manner laid down in our firſt Lecture.

*Preliminary Obſervation.*

2. All the phyſical Knowledge we can have of a Subject, muſt ariſe from attending to its Properties, and Effects. But theſe Properties and Effects can never be diſcovered, without the help of Experiments; which in phyſical Enquiries are the only Interpreters, betwixt the Senſes and the Reaſon. Whence, all thoſe Notions of Fire ſhou'd be rejected as precarious and unſound, that are taken from the direct Teſtimony of the Senſes; or the naked Reaſon, unaſſiſted by Experiments. In this Enquiry therefore, the Mind is particularly to be kept unprepoſſeſſed; and to wait for a full Information before it can pronounce.

*Fire how underſtood.*

3. By the general Name of *Fire*, Men ſeem to underſtand a certain Senſation, or complex No

tion

tion of Light, Heat, Burning, Melting, &c. This Notion ſhould be reſolved or analyſed; to ſee what parts are eſſential, and what precarious, or arbitrary.

*The Eye no judge of Fire.*

4. We frequently find the Effects of Fire produced, where no viſible Fire appear'd. Thus the Fingers are eaſily burnt by an Iron heated below the Degree of Ignition; or ſo as to be no way viſibly red-hot or fiery: whence the Eye is no Judge of Fire.

*The Touch no true judge thereof.*

5. So likewiſe, the Touch gives us no poſitive notice of any Degree of Fire, below the natural Heat of the Body, or of any ſo great, as to deſtroy the Organ.

*Burning, &c. not eſſential to Fire.*

6. Again, the Effects of Fire are often produced without any manifeſt Signs of Burning, Melting, &c. as in Evaporations, Exſiccations, &c.

7. If this Method of Excluſion and Rejection were purſued to its due length, we ſhould perhaps find no Criterion, infallible Mark, or Characteriſtick of Fire in the general, but that of a particular Motion, ſtruggling among the ſmall parts of Bodies, and tending to throw them off at the Surface. And if this ſhould prove the Caſe, then ſuch a Motion will be the *Form* or Eſſence of *Fire*, and which being preſent, makes Fire alſo preſent; and when abſent, makes Fire alſo abſent. Whence to produce Fire, and produce this Motion in Bodies, will be the ſelf-ſame thing *.

8. But the following Experiments will afford us more Light; and ſhew, (1.) That, in general, both Solids and Fluids manifeſt an expanſive Motion upon being heated. (2.) That the direct inflammable Matter of Fuel is Oil, or an unctuous Sub-

* See the Lord *Bacon's* Philoſophical Works, Engl. Ed. Vol. II. pag. 433, &c.

ſtance. (3.) That no Fuel will burn or conſume, without the Admiſſion of freſh Air. (4.) That the Air, which has once paſſed through burning Fuel, is of itſelf unfit to animate Fire again. And (5.) That Flame exiſts only on the Surface of Fuel.

### Experiment I.

*That Iron expands with Heat.*

9. We procured an Iron Ring to be made, juſt capable of admitting one end of a ſolid Rod of the ſame Metal; then heating that end in the Fire 'till it was red, and applying it to the Ring, we found the Rod ſo ſwell'd, that it would not now enter the hollow, which it exactly fitted when cold.

10. This Experiment directly ſhews no more, than that Iron expands upon being heated; but as it has alſo been found to ſucceed in many other Solids, it may be made general; 'till the contradictory Inſtances are produced in the way of Exceptions *.

### Experiment II.

*That Fluids expand with Heat.*

11. We filled the ſpherical Cavity of a bellied Glaſs, having a long and ſlender Neck, at three different times, with (1.) Mercury, (2.) Water, and (3.) Spirit of Wine, to the ſame height; then plunging the Glaſs, ſucceſſively, into Water (kept in the ſame Degree of Heat, in all the three Trials, as appeared by a Thermometer employ'd;) we found each Fluid ſwelled very remarkably, or roſe up to a conſiderable Height in

* Cedar Wood has, upon ſome Trials, been thought not to expand with Heat, or contract with Cold.

in the Neck of the Glaſs, above what it had before the Glaſs was placed in the hot Water.

12. This Experiment likewiſe ſeems to hold of all Fluids univerſally: ſo that for the preſent we muſt allow the Motion of Expanſion, or Rarifaction in Bodies, inſeparable from Heat, or Fire in the general.

## II.

*Three Species of Fire.*

13. We proceed to conſider this *general Fire* in its three Kinds or Species; *viz. Celeſtial*, *Subterraneous*, and *Culinary*.

*Celeſtial.*

14. By *Celeſtial Fire* we principally mean that of the Sun, without regard to the Fire of the fixed Stars; tho' this perhaps may be of the ſame nature.

*Subterraneous.*

15. By *Subterraneous Fire* we underſtand that which manifeſts itſelf in fiery Eruptions of the Earth, Vulcano's, or burning Mountains; and by any other Effects it produces in Mines; or the more central Parts of the Earth.

*Culinary.*

16. By *Culinary Fire*, we mean that vulgarly employ'd in all Chemical Operations; and the common Occaſions of Life.

*The Sun's Heat.*

17. The Sun's Heat appears to be the actuating Principle, or general Inſtrument of all the Operations in the Animal, Vegetable, Atmoſpherical, Marine, and Mineral Kingdoms *.

*The Purity of the Sun's Heat.*

18. Conſidered in itſelf, Fire ſeems to exiſt in greateſt Purity and Perfection in the Celeſtial Regions; at leaſt we are inſenſible of any conſiderable Smoke it yields: for the Rays of Light come to us from the Sun, unmixed with any of that groſs, feculent, or terreſtrial Matter, found in Culinary and Subterraneal Fires. And allowing

* See *Lect.* I. §. 16.

ing for this Difference, the Effects of the Solar Fire appear the same, as those of Culinary Fire.

19. To examine also the Effects of *Subterraneous Fires*, we shall find them the same with those produced by Culinary Fire. Thus burnt Coals, Cinders, and melted Minerals are thrown up by *Vesuvius*, and other burning Mountains. Warm mephitical Exhalations, natural hot Springs, Steams, Vapors, Smoak, *&c.* are found in several parts of the Globe; rising nearly in the same manner, as if they were produced by the Heat of a Furnace. Whence there is little room to doubt, that the Subterraneous Fires are of the same nature with the Culinary. *Subterraneous Fire approaches the Culinary.*

20. And as all the three kinds agree in giving the Motion of Rarifaction to Bodies; it seems no way improper, to reduce the three Species of Fire to one, or to quit, for the present, the Celestial and Subterraneous, and keep to the Culinary Fire, which is more within our command; and every where ready at hand, for Experiments. *The three Kinds have a near Agreement.*

21. All Culinary Fire requires some Pabulum or Fuel, wherein it resides, or is collected. A leading Experiment therefore, in our present Enquiry, is the Analysis of Fuel, to discover its constituent Parts, and learn which of them is more immediately adapted to receive, or propagate Fire. *Fuel what.*

## Experiment III.

### *That Oil is essential to Fuel.*

22. We put a Pound of common Billet-Wood, reduced to small Pieces, into an earthen Retort, and distilled with a naked Fire, into a large Glass Receiver. There came over (1.) an acid Water, (2.) a reddish tart Liquor, (3.) Smoke, and a gross *A leading Experiment.*

groſs black and burnt Oil. The Fire being kept up ſtrong at laſt, no more Liquor or Oil aſcended; but (4.) a black Matter, exactly reſembling Charcoal, remain'd behind; and being taken out of the Retort, and burnt in the open Air, it reſolved to Aſhes; which Aſhes, by Diſſolution in Water, afforded (5.) a little fixed Salt, and (6.) an earthy Subſtance.

*That Coals owe their Inflammability to Oil.*

23. This Experiment appears to be general, or to ſucceed alike in all Wood, Coals, or ſolid Fuel. We ſeparated the acid Water, or reddiſh Liquor from the Oil, by the Filtre; and then found that theſe aqueous Liquors would not burn in the Fire, no more wou'd the Aſhes, the Salt, or the Earth, either ſingle, or in compoſition: ſo that of all the Subſtances thus obtained from the Wood, the black Coal and the Oil are the only inflammable ones. But the Coal remains inflammable, merely upon account of the groſs Oil ſtill lodged, and cloſely locked up therein; and according to its peculiar nature, ſcorched, or turned black by the Heat employed in the Operation.

24. If farther Evidence be wanted to prove it is the Oil remaining in the Coal, that gives the Blackneſs and Inflammability; let it be conſider'd, (1.) That all ſcorched Oils turn black; and that the more volatile Oil, which here comes over into the Receiver, is black. (2.) That no other part of the Wood, ſeparated by the Analyſis, is inflammable, beſides the black Oil; not the Coal itſelf, after it is become white, or reduced to Aſhes, by open Fire and Air: which is an Operation ſufficient to diſlodge the groſs black Oil that could not be raiſed by a leſſer Force. (3.) That no other chemical Cauſe can be well aſſigned of this Blackneſs and Inflammability. (4.) That Wood, Pit-Coal, *&c.* prove leſs inflammable

mable, the more they are deprived of their Oil. (5.) And laſtly, that the Calces of Metals being rendered abſolutely uninflammable by Calcination, appear to attract this Oil out of burning Fuel, ſo as thence to recover their inflammable Principle, and true metalline Form *.

25. But without farther Proof we may venture, for the preſent, to conſtitute Oil the ſole Principle, or inflammable Matter in Fuel; and on this footing it will be proper to reduce our Enquiry to the more oily Species of Bodies; and make our Experiments chiefly upon thoſe.

## Experiment IV.

*That Fire will not conſume Fuel without the Admiſſion of Air.*

26. Having exactly fitted a hollow Cylinder of Iron, with a ſtrong Skrew at each end; we included a long Piece of Charcoal in the Cavity; then skrewing both Ends tight, we detained the Cylinder in a ſtrong Fire, for ſeveral Hours; and afterwards letting it cool, we took out the Charcoal, and found it ſtill black, and no way apparently conſumed, altered, or diminiſhed.

27. This Experiment, compared with the common Obſervation of Fuel, burning and conſuming quick in the open Air, ſhews that Air is neceſſary to the Conſumption of Fuel; or that its burning and conſuming depend upon the Rarifaction, Diſlodgement, briſk Agitation, and Diſcharge of the Oil it contains: which is the phyſical Cauſe of the Effect. And hence we have the reaſon

* Let proper Trial be made, to ſhew whether the fixed Oil cannot be ſeparated from powder'd Charcoal, by a ſtrong Lixivium of Pot-aſh and Quick-lime, ſo as to form a Soap; or otherwiſe exhibit this Oil to the Eye. See *Lect.* XVIII. §. 22.

reaſon of the known Rule or Method of extinguiſhing Fire by ſmothering it; or keeping it cloſe from the Air.

28. But that the bare Motion of confined Air, or its paſſing ſeveral times through lighted Fuel, is not capable of conſuming the Fuel, appears by the following Experiment.

## EXPERIMENT V.

*That Air which has paſſed thro'* Fire, *or ignited Fuel, is unfit to animate Fire again.*

29. We cauſed a wooden Box to be made, perfectly cloſe and tight, with Glaſs Windows on the ſides. At the bottom of this Box was a Perforation exactly fitted with a hollow wooden Plug, that joined to a tight leathern Pipe. This Pipe at the other end communicated with the Clack of a pair of Hand-Bellows, the Noſe whereof entered at a Hole on one ſide of the Box; ſo that by this Contrivance, when the Bellows were worked, it was eaſy to draw the Air out of the Box into the Cavity of the Bellows, and return it into the Box again, without admitting any other Air, beſides that originally contained in the Box. We now ſet a little Chafing-Diſh of live Coals in the middle of the Box, and ſecuring all the Joints tight from the external Air, we plied the Bellows; which, inſtead of increaſing, ſoon totally extinguiſhed the Fire; tho' the Coals were by no means burnt to Aſhes, but remained black and freſh when cold.

30. Hence it is manifeſt, that even a brisk Motion of ſuch Air as has already paſſed through burning Fuel, is ſo far from animating, that it deadens or quenches Fire *, in the manner of damping

* Let a proper Experiment be deviſed, to ſhew what Alteration the Air ſuffers by paſſing through Fire.

Damping or Smothering; the Oil of the Fuel not being carried off for want of freſh Air.

31. This method of damping Fuel, or ſuffering it firſt to burn a little, and then extinguiſhing it, teaches us a Method of rendring Fuel inoffenſive, and fit for the more curious Uſes, by diſcharging its groſs Smoke, ſo as to leave a pure charred Coal behind. *Fuel how charred.*

Thus for example, if Pit-Coal or Wood be burnt, not in the open Air, but with a cover'd, cloſe, or mouldring Heat, 'till it cauſes it to fume, and be then immediately more ſmother'd or quench'd by the throwing on of Mould, Sand, or Water, it thus becomes a charred Coal or Coak, fit for the drying of Malt, or other curious Operations, where groſs Smoke would be prejudicial.

32. Another Method of obtaining a pure Fuel, is to chuſe ſuch an inflammable Matter, as yields little or no Smoke from the firſt; ſuch, in particular, as Spirit of Wine; or, in the next degree, Oil of Turpentine, or other thin *ethereal Oils*, as they are called; of which, Spirit of Wine is by the Chemiſts deſervedly reckoned the fineſt or moſt ſubtile *.

## Experiment VI.

*That Flame dwells and plays only about the Surface of Fuel.*

33. We filled a Lamp-Glaſs with Spirit of Wine, and another with Oil of Turpentine; then ſetting fire to each Liquor, it was viſible thro' the ſides of the Glaſſes, that both Liquors burnt or flamed only on the Surface; the Flame continually ſinking lower and lower in the Glaſſes, as the Liquors conſumed.



* See *Lect.* VI. and XIII.

34. This Experiment holds alſo of ſolid Fuel, and appears to be univerſal. And hence again we are directed in the choice of our Fuel; which to light quick, ſhou'd be furniſhed with a thin ſubtile Oil on its Surface. And upon this Foundation depend thoſe ſudden Methods of illuminating, practiſed at great Entertainments or publick Rejoicings. And upon the ſame Principle we might eaſily invent quick, commodious, and inoffenſive Ways of lighting common Fires, &c.

## III.

*The Effects of Fire.* 35. Having learn'd how to procure, prepare, manage, and improve our Fuel*; we come, in the next place, to conſider the Effects of the Fire, produced by its means, on the Atmoſphere, and Bodies of the terreſtrial Globe.

*On the Atmoſphere.* 36. All Fire rarifies the Air that is near it, as appears from a Bladder including a ſmall Portion of Air, and lying in a warm place, or before a Fire; for thus the Air is made to ſwell and diſtend the Bladder: Whence the Atmoſphere muſt needs be rarified by the Sun's Heat, and produce its Effects accordingly. The Air alſo imbibes Smoke, and carries it aloft; at the ſame time that the Fuel diminiſhes or waſtes, and falls into Aſhes. Whence the Air becomes a kind of Menſtruum, impregnated with Smoke, or the matter of Soot, in places where much Fuel is conſumed †.

*Upon particular Bodies.* 37. The Effects which Fire has upon particular Bodies, can only be learned from particular Experiments; to make which, is the more immediate Office and Uſe of Philoſophical Chemiſtry. Thus in ſome Bodies, as Ores, Fire procures

* See above, §. 25, 26, 27, 28, 29, 31, 32, 33, 34.

† See *Lect.* III. *paſſim*. See alſo *Lect.* I. §. 16.

cures Fusion and Separation; in others, as Sand and Pot-ash, Fusion and Mixture; in some Dryness and Exsiccation, as in Clay; in others Softness and Pliability, as in Wax, *&c.* according to the Degree and Manner, wherein the Fire is applied. But for the conduct to be observed in this Application, certain general Rules are required. And first with regard to the kinds of Heat,

38. There are in Chemistry as many kinds of Heat, as there are Mediums thro' which it may be conveyed; or Fuels that afford it. *The kinds of Heat in Chemistry.*

39. For common use, Heat is conveyed either thro' Water, Ashes, Sand, *&c.* or directly thro' the containing Vessel.

40. When Heat is conveyed thro' Water, 'tis called the *Balneum Mariæ*, or Water-Heat; when thro' Ashes, an Ash-Heat; when thro' Sand, a Sand-Heat; and when thro' no intermediate Substance at all, a naked Fire. Balneum Mariæ, *Sand-Heat*, &c.

41. Some Differences may be found in the Effects produced by these different Heats, applied in the same Degree. But they have not perhaps been noted as they deserve.

42. In several Bodies 'tis evident, that dry and moist Heats have different Effects; which we find remarkably in the common culinary Operations of boiling, roasting, baking, *&c.* And hence, where the Effects are required perfectly similar, the same kinds, as well as degrees of Heat, are to be used.

43. The purest Fire is that of Alcohol, or perfectly pure Spirit of Wine; the next in purity is that of distilled Oils; the next, that of Charcoal, or charred Turf; and the impurest, Pit-Coal: But all these have nearly the same Effect, when received thro' the same kind of Medium. *The Degrees of Purity in Chemical Fires.*

## IV.

*The Degrees of Heat.* 44. The laſt thing to be conſidered, is, how to regulate and aſcertain the Degrees of Heat in Chemical Operations; ſo as to produce the Effects required in every Caſe.

*Uncertain.* 45. The common Directions of the Chemiſts about this Matter are full of Uncertainty; their firſt, ſecond, third, and fourth Degrees of Heat, meaning no preciſe Degrees, meaſured by any Standard.

*How to be regulated.* 46. To reduce this Affair to the neceſſary Accuracy, proper Thermometers might be employed; filled either with Oil or Quickſilver, and graduated from the freezing Point, or any other fixed Point of Cold, up to the Degree of boiling Quickſilver. Thus would come in their *The firſt Degree.* reſpective Places, (1.) the Degrees of Heat beſt ſuited to Vegetation, which might be ſerviceable in regulating the Temper of Green-Houſes. And this temperate Heat is ſuited to extracting of the native Spirits of odoriferous Vegetables with Oil; as that of Roſes, Jaſmin, *&c.* and again, to making the more curious Inſolations, *&c.*

*The ſecond.* 47. (2.) The next Degree may be accounted that of the human Body in a healthy State; this Heat is always greater than that of the ambient Air. But when the Body is dead, it receives the ſame Degree of Heat with the ambient Fluid. This ſecond Degree of Heat is adapted to vinous and acetous Fermentation, Putrefaction, Excluſion of the Chick; the finer Digeſtions, the making of Tinctures and Elixirs; and the Adepts have uſed it for the firſt Digeſtion of their Mercury, by carrying the including Veſſel conſtantly in their Pocket.

48.

48. (3.) The third Degree of Heat in this Progreſſion, may be that of boiling Water, when the Atmoſphere is in a middle State of Rarifaction. This Degree of Heat is required in the Diſtillation of ſimple and compound Waters, the eſſential Oils of Vegetables, and will coagulate or conſolidate the Serum, Blood, and other animal Juices; and conſequently deſtroy the Creatures. *The third.*

49. (4.) A fourth Degree of Heat may be that, wherein Quickſilver or Oil of Vitriol boils, diſtils, or becomes volatile. This Degree is ſuited to the melting of Lead, Tin, Biſmuth, *&c.* the ſubliming of Sal Armoniac, and Sulphur; the calcining of Antimony, *&c.* *The fourth.*

50. (5.) A fifth Degree of Heat may be that wherein Iron is kept in thin Fuſion. By this Degree of Heat all the other Metals are melted, *viz.* Gold, Silver, and Copper; Glaſs is made, and the unvitrifiable Stones calcined. *Fifth.*

51. (6.) The ſixth and higheſt Degree of Heat hitherto known, is that of the burning Lens, or Concave, by M. *Villette*, *Tſcirnhaus*, and others. The Focus of theſe Claſſes will even volatilize what is called the Metalline or Mercurial part of Gold, and vitrify the more terreſtrial. *Sixth.*

52. And thus much for regulating the Degrees of Heat to be employed in Chemical Operations. We muſt next conſider by what means the preceding Degrees of Heat may be excited and preſerved, as occaſions require. *The Degrees of Heat how raiſed and preſerved.*

53. (1.) The Fuel muſt be choſe ſuitable to the Intention. The natural Sun in Summer ſuffices for Inſolations. A Spirit-Lamp may be made to give a moderate, or a conſiderably ſtrong Heat, according to the number of Wiecks employed. And its Strength may be eaſily meaſured and adjuſted by the Thermometer.

54. (2.) The lighter Fuels, such as Straw, Leaves, Twigs, &c. come next in order, after Spirit of Wine. (3.) Then Oils, Wax, Rosin, Pitch, &c. And (4.) lastly, solid Wood, Coals and Turf; all which may have their proper Furnaces, so as to be burnt, in the requisite Quantity, with the requisite Fierceness or Slowness.

*The greatest Heat with Fuel.*

55. To excite the greatest Degree of Heat in a Furnace, the Rule is to use the densest Fuel, in the largest Quantity, and with Bellows all round the Furnace, incessantly blown, and directed to the central Point of the Fire, wherein the Matter to be acted upon is lodged. And in this manner may be procured a Degree of Heat, sufficient for any of the known Operations upon Metals, Minerals, Glass, &c. that require the strongest culinary Fire*.

## V.

### AXIOMS *and* CANONS, *for the better Knowledge and Regulation of Fire.*

We learn from the preceding Enquiry;

1. That the direct Senses afford but little Information, as to the real Nature, essential Properties, or *Form* of *Fire* †.

2. That the *Form* of Heat and Fire is a certain bridled, or restrained Motion, excited, maintained, and struggling in the minute parts of Bodies; and tending to throw them off at the Surface ‡.

N.B. *If this* Form *be rightly discover'd, then to introduce such a Motion among the Parts of any Body,*

* If more be desired upon this extensive Subject, the Reader may consult the Lord *Bacon*, Dr. *Hook*, Mr. *Boyle*, Mr. *Evelyn*, Dr. *Bohn*, M. *Homberg*, Dr. *Boerhaave*, and Dr. *Stahl*.

† See above §. 3, 4, 5, 6, 7, 33.

‡ See §. 7, 8, 9, 10, 11, 26, 27, 28, 29, 32, 33, 34.

*Body, will be to introduce Heat; or if the Nature of the Body be capable of it, Ignition or Inflammability.*

3. That as the direct inflammable Matter in all Fuel, is the Fat or Oil it contains*; the moſt oleaginous Fuel is the beſt, or richeſt.

4. That Flame is the ſmall Parts of an inflammable, or conſiderably unctuous Body, that are ſet on fire, or briſkly agitated and thrown off, with a certain vibrative Motion, at the Surface of that Body, into the open Air†.

5. That Flame cannot exiſt without Oil‖. Whence it is, that Aſhes, Sand, Glaſs, Stones, and Earths, do not flame upon Ignition; but rather damp and extinguiſh Flame.

6. That as Oil is the only inflammable Subſtance in nature**; this may direct us to the means of preventing Conflagrations; *viz.* by uſing ſuch Materials in Buildings, as contain little or no Oil. And this Direction might be likewiſe extended to the making of incombuſtible Paper; for valuable Books and Manuſcripts; and new Materials for Hangings, Furniture, *&c.*

7. That as all Flame catches and exiſts only on the Surface of inflammable Bodies††; we are hence led to invent Methods of caſing, or otherwiſe defending the Wood-work of Ships, and Buildings from Accidents by Fire.

8. That as the three capital kinds of *Fire* have a near relation, and may be very well reduced to one, for human Uſes, *viz.* the culinary kind‖‖; Men may have reaſonable Hopes of performing conſiderable things by its means, in



* See above, §. 22, 23, 24, 25, 33, 34.
† See above, §. 26, 27, 29, 33, 34.
‖ See above, §. 22, 23, 24, 25, 33, 34.
** See above, §. 22, 23, 24, 25, 33, 34.
†† See above, §. 33, 34.
‖‖ See above, §. 13—20, 34, 36, *&c.*

imitation of Nature; as particularly in promoting and regulating Vegetation, the Ripening of Ores, &c. by artificial Heats.

9. That Fire and Flame are aboliſhed or extinguiſhed by Suffocation; or an Action contrary to Ventilation *, as being deſtructive or preventive of that internal Commotion, and Diſcharge of the oily Particles of Fuel, by means of the free Air, wherein the nature of open and conſuming Fire and Flame conſiſts. † And hence Fire and Flame are quenched by Water; or even by Spirit of Wine, or Oil of Turpentine; if a live Coal, or lighted Candle, be ſuddenly plunged therein, below the Surface of the Liquor. For the Degree of Heat, which Water, Spirit of Wine, or Oil of Turpentine unfired, are capable of receiving, is much leſs than that of a burning Coal or Candle; whence the greater Heat is ſubdued by the leſs; as Fire is quenched by boiling Water.

10. That Heat is Fire in a leſs Degree, and Fire no more than a greater Degree of Heat; whereon Lucidity, and, if the Matter be unctuous, Inflammability ‖, depend: as we ſee in hammering a Piece of Iron, 'till it becomes red-hot; and in the firing of Wind-mills, or Coach-wheels, by their own violent Motion.

11. That Heat muſt aggregate and collect in a certain Proportion, before it become cognizable to the Senſes, and produce any manifeſt Effects of Fire or Flame. Thus a Degree of Heat below that of the natural human Body, is inſenſible, or paſſes for a Degree of Coldneſs; and the ordinary Motion of Windmills, Carriages, &c. produces

* See above, §. 26, 27, 29, 30, 31. See alſo *Axiom* 2. foregoing.

† See above, *Exp.* III, IV, V, and VI.

‖ Ibid.

duces no remarkable Heat; tho' when the Motion is greatly increaſed, or the Friction large, it ſoon excites Fire and Flame *.

12. That all the Chemical Operations require a certain or determinate Heat, in order to perform them with the greateſt advantages; and that this Heat may be aſſigned and obtained, in every caſe, to the great Improvement of Chemiſtry †.

* See above, §. 3, 4, 5, 6, 7.
† See above, §. 44—55.

LEC-

# LECTURE III.

CONTAINING,

(1.) *The general Properties*; (2.) *Ingredients*; (3.) *Nature*; (4.) *Office and Uſe of the Atmoſphere.*

(5.) *The Changes therein*; (6.) *The Effects it produces on the Terreſtrial Globe*; *and* (7.) *in Chemical Operations.*

## I.

*The Subject.*

1. WE are now to enquire into the Chemical Nature, Properties, Ingredients, Office and Uſe of the Atmoſphere.

*The Atmoſphere what.*

2. By the *Atmoſphere* we underſtand, that whole Maſs of rarified Matter, or dry Fluid, which ſurrounds the Globe of the Earth to a conſiderable height.

*Its Import to Chemiſtry.*

3. To diſcover the Nature, or Influences and Effects of this Fluid, is of the utmoſt importance to Chemiſtry; it being the general Fluid wherein all Animals, Vegetables, and Minerals grow; and wherein our Fires burn, and every Chemical Veſſel and Object is included.

*To be examined in three States.*

4. We ſhall examine it as exiſting in three States, *viz.* (1.) As it is an entire Maſs, that ſurrounds the whole Terraqueous Globe; (2.) As it conſiſts of *diſſimilar Parts*, whilſt it either lies open, and remains one with the reſt, or elſe is ſeparated therefrom by being included in our Glaſſes or Veſſels; and, (3.) As it is united with, or fixed in Bodies. And by thus examining the

Parts

Parts of this general Fluid in different places, we may infer the nature of the whole.

## Experiment I.

*That different Effluvia mix and form Clouds, or unite in the* Atmosphere.

5. We unstopped a Bottle of the strong Spirit of Sea-Salt, and another of the volatile Spirit of Sal Ammoniac; and setting the Bottles near each other, the Vapours insensibly arising from each, met and formed themselves into a very gross visible Fume, or actual Cloud, that continued for some time, but afterwards disappeared, or mixed more intimately with the Air of the Room. *That the Atmosphere receives Vapours.*

6. One of the Liquors here employed is an acid Spirit; and the other an alkaline one, and being mixed, they form a Species of neutral Salt, or Sal Ammoniac. And as their Fumes are no other than fine Parts of the Liquors themselves, that still retain their Natures, they constitute this kind of neutral Salt in the Air.

7. That something of the same kind will naturally happen in the Atmosphere, appears from hence, that all Vegetables produce a kind of volatile Salt by Putrefaction; and the volatile Salts of putrefying animal Substances, no less than the former, naturally go up into the Air; where some Proportion of Sea-Salt must likewise be raised from the Earth and Ocean: so that if these Particles meet, they will necessarily make a kind of Ebullition, and unite into a neutral Substance, in the Atmosphere; which may hence abound with a variety of acid, alkaline and neutral Salts, the Signs whereof are evidently discovered by the Changes they make, in th[illegible]rs of different Bodies.

8. This Experiment therefore may ſhew to the Eye ſomewhat of the phyſical manner wherein Clouds and Meteors are generated in the Atmoſphere; and teach us that Salts naturally abound therein: whence we have the phyſical Reaſon of many Effects produced by the atmoſpherical Air, in the animal, vegetable, and mineral Kingdoms, and again in many Chemical Operations.

9. But that the Atmoſphere not only ſupports Vapours or Effluvia raiſed into it from the Earth, but alſo preſſes upon terreſtrial Bodies by its Weight, appears from many Pneumatical Experiments; of which kind we need only produce two or three for the preſent.

## EXPERIMENT II.

### *That the Atmoſphere preſſes upon Bodies by its Weight.*

*The Preſſure of the Air.*

10. This was made ſenſible to the Hand applied cloſe on the top of a hollow metallic Cylinder, or Ring, about two Inches in Diameter, ſet upon the Air-Pump; for when the Air is drawn out of the Cavity of this Ring, the Hand upon it will be remarkably preſſed inwards, and feel a conſiderable weight.

11. The Effect was likewiſe ſhewn in a different manner to the Eye, by breaking a piece of flat Glaſs, applied cloſe to the top of the ſame metallic Ring: for whilſt the Air was drawn away from below, the Glaſs was immediately cruſhed to pieces, and made to fall inwards, with a loud noiſe and a conſiderable force.

*The Air's Elaſticity.*

12. Beſides this Weight, or Preſſure, the Air or Atmoſphere has likewiſe an elaſtic Force, which is no leſs conſiderable; as appears by many Examples; and particularly by the following.

Ex-

## Experiment III.

*That Air is elaſtic, or capable of forcing, diſtending, or ſqueezing Bodies by its Spring.*

13. We included a little Air in a Bladder, ſo as to leave it almoſt flaccid; and, the Neck being cloſe tied, put it into a Receiver, and then exhauſted the Air out of the Glaſs, (but not out of the Bladder;) upon which the Bladder immediately ſwelled, and appeared as if full blown: but upon re-admitting the external Air, the Bladder was preſently ſqueez'd up, or contracted, to its former Dimenſions.

14. The ſecond and third Experiment therefore ſhew that the Air, or Atmoſphere, both in its natural unconfined State, and when certain Portions thereof are included in Veſſels, continually exerciſes a gravitating and elaſtic Power, capable of producing many Effects; as continually preſſing, by its Weight and Spring, all the Bodies we know. It perpetually preſſes upon the Surface of the Earth, with a weight equal to that of a Column of Quickſilver, whoſe Baſis is that Surface, and whoſe Height is about 29 Inches, as manifeſtly appears by the Barometer.

15. Hence the Atmoſphere will inſinuate itſelf into the open Pores on the Surfaces of all Bodies, capable of receiving its component Particles. So that the Pores of many Subſtances, which to our Senſes appear Vacuities, are full of common Air; which thus produces the proper Effects of Air, in Diſtillations, and many other chemical Operations.

16. The Atmoſphere alſo as a Fluid, muſt by the Laws of *Hydroſtatics* preſs Bodies equally every way, and the internal Air of Bodies acting within, whilſt the external Air acts without, numerous

merous physical Effects are hence produced in that great Laboratory, the Earth; where Bodies thus by natural Powers, and Agents, dissolve, putrify, change, and are carried off into that grand Repository the Air.

*The Effects, and compounded Nature of the Atmosphere.*

17. And tho' the Atmosphere itself be invisible, yet we cannot but be sensible of the Effects it produces, as being, by means of proper Contrivances and Observation, rendred sensible even to the Eye, as in the preceding Experiments. And thus, tho' the Atmosphere be a rarified and moveable Fluid, so that Bodies easily pass thro' it; yet broad Surfaces are greatly resisted by it. And hence its Force, as a resisting Fluid, becomes manifest in high Winds, by driving and dissipating the Clouds, and all kinds of Vapours and Exhalations; which are thus mixed in with the Mass of the Air, so as to form a heterogeneal Fluid, or Chaos of infinite Materials.

## EXPERIMENT IV.

### *The Construction, Nature, and Use of the common Thermometer.*

*Thermometers explained.*

18. (1.) The common Thermometers are Glass-Tubes filled with tinged Spirit of Wine, and graduated, so as to shew, by the rising or falling of the Liquor, the Degrees of Heat whereto it is exposed.

19. (2.) Spirit of Wine is chose for this purpose, because it is the most rarifiable Fluid with Heat, hitherto known, next to the Atmosphere itself. Denser Fluids might be employed, but the Division would then be less; and Water is unfit for this purpose, as freezing with Cold.

20. (3.) These Thermometers are the exactest Instruments hitherto known for measuring of Degrees of Heat; being filled either with Alcohol, Brandy,

Brandy, Oil, or Quickſilver, according to the ſeveral purpoſes for which they are deſigned *.

21. (4.) The common Thermometer ſhews the warmth of the Air; and that it always contains a greater or leſs Degree of Fire, or Heat: for Spirit of Wine has never been found to freeze or congeal with any Weather, or in any Climate; but riſes and falls in the Tube, as the Weather is more or leſs hot; with regard to which alſo the Atmoſphere frequently varies.

## Experiment V.

### *To determine the Proportion of Water contained in an aſſigned Portion of the Atmoſphere.*

22. Having, by means of the Air-Pump, and an exact Pair of Scales, found the weight of a certain quantity of Air, contained in a large Glaſs Veſſel; we included therein a known weight of well-dried Potential Cautery (whoſe Property it is powerfully to attract the Moiſture of the Air;) and kept this Veſſel cloſe ſtopped for ſeveral Hours; during which time, the Potential Cautery was grown wet: in which ſtate being weighed again, we found a conſiderable Increaſe, which muſt either be owing to the Water attracted out of the Air in the Glaſs; or to a Condenſation of the Air itſelf into an aqueous Fluid: for ſuch a Fluid might now by Diſtillation be obtained from the Matter thus run *per deliquium* †. *Water in the Air.*

23. There is ſome room to ſuſpect, that if this Experiment were made in perfection, a weight of Water, almoſt equal to that of the Air included in the Veſſel, might be thus obtained, which might prove a very extraordinary Diſcovery; and ſhew

* See *Lect.* II. §. 46.

† The Experiment was not made with all the requiſite Exactneſs.

ſhew what ſome have endeavoured to prove, that the Matter of common Air is little more than Water *.

24. That much Water muſt needs be contained in the Air, appears evident from the quantity daily exhaled, by the Sun, from the Ocean, the Rivers, and the whole animal, vegetable, and mineral Kingdoms. And as the Water ſo raiſed into the Atmoſphere muſt neceſſarily mix and join with the ſaline and other Particles it there meets with, and is capable of diſſolving; hence the Water of all our Springs, Rivers, and the Ocean itſelf is impregnated with infinite Matters, that little appear in Water. And poſſibly to give the animating or vivifying Spirit to Water, it is phyſically neceſſary, that it ſhould be perpetually refined or refreſhed by this kind of Diſtillation, or recruited and new impregnated with the Effluvia or fine Particles of all the Bodies floating in the Atmoſphere; after the ſame manner as a ſkilful Operator, to give his diſtilled Waters the finer Impregnation, ſuſpends a proper Mixture of Ingredients, in the Head of his Still.

## EXPERIMENT VI.

*That a Refreſhment or Renewal of Air is neceſſary to Life.*

*Freſh Air required in Reſpiration.*

25. If an Animal or Plant be long continued in the ſame quantity of cloſe, unchanged, or unrefreſhed Air; they will languiſh and expire much after the ſame manner as Fire would do by a kind of Suffocation †.

26. Hence it appears that the Air, which has once ſerved for the Reſpiration either of an Animal or Vegetable, is unfitted for the ſame Office again

* See the Lord *Bacon*'s Natural Hiſtory of Winds, *paſſim*.

† See *Lect.* II. §. 29, & alibi, *paſſim*.

again, till it be recruited; as it ſeems to be, by mixing with the open Atmoſpherical Air. Every Man is computed thus to deſpoil a Gallon of Air in a Minute; whence, if the number of Animals and Vegetables on Earth be conſider'd, it ſhould ſeem that the whole Atmoſphere muſt in time be deſpoiled, unleſs ſome natural means were uſed to prevent it. And to conſider the matter attentively, one might ſuſpect that the Particles of infinite Materials ferment* together in the Atmoſphere, and produce a certain *Spirit*, or fine vivifying Subſtance, that thus renovates and invigorates the whole Maſs, and renders it again fit for Reſpiration, and the Suſtentation of all Natural Bodies. And hence perhaps it is, that no ill effects are uſually felt from that immenſe quantity of groſs Smoak continually diſcharged into the Atmoſphere of large Cities. All Bodies ſuffer a kind of Tranſmutation, and may by the eſtabliſhed Courſe of Nature go the ſame rounds again. And hence alſo no wonder that Air, when it is ſo richly impregnated with Water, Soot, Smoak, Salts, Oils, Kitchen Exhalations, *&c.* ſhould prove in ſome degree Nutrimental.

## Experiment VII.

*That looſe Air is contained in Fluids.*

27. We ſeverally put Water, Small-Beer and Brandy, into an Air-Pump Receiver, and exhauſting the Air, obſerved numerous Bubbles to ariſe and eſcape from each Liquor; or burſt upon the Surfaces thereof. *Air in Liquors.*

28. And in like manner is Air diſcharged from Liquors, by boiling them over the Fire: This is practiſed upon Water, in order to make it



* See *Lect.* VII. paſſim.

it afford Ice without Blebs or Bubbles; and again upon Oil, design'd for *Thermometers*, &c. But by standing open, such Liquors as have been thus discharged of their loose Air, will be found to recover it more; as if loose Air were a kind of natural Ingredient in Liquor.

## EXPERIMENT VIII.

*That the external Air may promote Solution.*

*The Air may promote Solution.*

29. We set some Spirit of Sal Ammoniac, and Copper-Filings *in vacuo*; and compared this with a like parcel, standing, for the same time, in the open Air: that *in vacuo* had not coloured its Menstruum; whilst that in the open Air afforded a rich blue Tincture. Hence it appears, that the free access of the external Air may promote Solution in some Cases; where it seems to act by increasing the Motion or Action of the Menstruum.

## EXPERIMENT IX.

*That the external Air does not promote Solution in all Cases.*

*Tho' in some Cases only.*

30. Upon two Drams of whole Crabs Eyes, *in vacuo*, we pour'd two Ounces of distilled Vinegar, first boiled to get out the Air. A great Ebullition was immediately produced, the Gage sunk, and Air was generated.

31. Upon comparing this with the same Experiment made in the open Air; we found that the Ebullition was much greater *in vacuo*, than in the open Air.

32. Hence we learn, that Air may be generated upon the mixture of certain Bodies, where it did not appear before.

33.

33. But this kind of Experiments muſt be made with Caution, the quantity of Air thus generated in ſome caſes being able to raiſe the Receiver, and throw it to a conſiderable diſtance.

34. There is wanting an Account of all the mixtures, that will produce Air in ſo violent a Degree; among them may be reckon'd *Oil of Vitriol*, with *Oil of Tartar per deliquium*, *Aqua-Fortis*, with Iron Filings, Spirit of Nitre, Oil of Caraway, *&c.*

35. And thus Air may be generated betwixt Solids and Fluids; and betwixt Fluids and Fluids, by bare mixture. The following Experiment will ſhew, that Air may be extricated out of Solids; and makes a conſtituent part thereof.

## Experiment X.

*That Air enters the Compoſition of Solid Bodies.*

36. We put a Piece of hard Tallow into an Iron Retort with a long neck; then laying the large end of the Retort in a naked Fire, and plunging the ſmall one into Water, we diſtilled in the uſual manner; and obſerved that large Bubbles of Air continually roſe, and diſcharged themſelves thro' the Water into the Air of the Room. Then at length ceaſing the operation, and collecting all the viſible matter left behind, or come over into the Water, we found a very conſiderable loſs of weight, owing to the Air, ſeparated or forced by the ſtrong heat from the reſt of the Tallow *. *Air in Solids.*

37. If it be objected, that the loſs of weight, might, in great meaſure, be owing to the Iron of the Retort, which, when hot, has the property of drinking in Oil, or Tallow; it may be obſerved,



* The Experiment was not made with requiſite Care and Caution.

ved, (1) that the effect is nearly the same when an Iron Retort is employed, that has been uſed for the ſame operation before; (2) that the Experiment anſwers proportionably when made in Glaſs; (3) that other Bodies beſides Tallow; particularly Hartſhorn, Bone, Tartar, &c. yield plenty of Air, when treated in the ſame manner: (4) as there is ſo large a quantity of Air-Bubbles diſcharged in the Operation, and as Air is proved to be a ponderous Body *; the loſs of weight may be fairly attributed to the eſcape of the Air. But (5) a proper Gage may be contrived, to determine the exact proportion of the Air, thus ſeparated, with reſpect to the original Matter, or Subject employed †.

38. This Experiment is of great importance in Natural Philoſophy and Chemiſtry. When fully verified and duly proſecuted, it may ſhew (1) that all natural Bodies conſiſt of a very large proportion of Air; as one part of their orignal Compoſition. (2) That Air is neceſſarily required to the Formation, and Growth of Animals, Vegetables and Minerals. (3) That when Bodies are diſſolved or reſolved, a great part of them turns into Air again; as when a Candle is burnt out, or Fuel conſumed; or as when Vegetables, Animals and Minerals ferment, putrefy or corrupt; or as when Bodies are chemically analyſed, or treated by Heat.

39. (4) That the Matter which in the Diſtillation of Hartſhorn, Tartar, and many other things explodes and puffs thro' the Luting, or ſometimes, when confin'd, burſts the Glaſſes or Veſſels, is the Air ſet free by the Heat.

40.

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* See above *Exp.* II.

† See Mr. *Hale's Vegetable Statics*, under the Analyſis of the Air.

40. (5) That the Air thus naturally condenſed, conſtituted and intermix'd as a conſtituent part in Bodies, has a great ſhare in their diſſolution; when being violently rarified, it breaks the parts in pieces, where it paſſes and flies off.

41. (6) But leaving the Experiment to be further verified, and made general, if capable thereof; we ſhall anticipate no more, but proceed to reap the Fruits of the preſent Enquiry.

## II.

### Axioms *and* Canons *derived from the Enquiry.*

1. We learn from the preceding Enquiry, that the Atmoſphere, conſidered as a Whole, and again as conſiſting of an infinite Number of Ingredients; is the Phyſical Cauſe of numerous Effects, not only in the Air itſelf, but likewiſe upon the Surface of the Earth, in the ſubterraneal Regions, in the exerciſe of numerous Arts, and particularly in Chemical Operations *.

2. That it is the phyſical Office and Uſe of the Atmoſphere, to aſſiſt in raiſing the Vapours and Exhalations of the Earth †; and ſerve as a general Matrix for them ‡; wherein they are all blended together, and fermented, or ſome way changed in their Nature, ſo as to perform new Offices, or recruit the Vegetable, Animal and Mineral Kingdoms, when ſuch enriched Vapours fall back again in Rain or Dew to the Earth ‖.

3. That it is the Nature of Air to inſinuate itſelf into Fluids **, unite and fix in Solids, ſo as



* See above *Exp.* II. III. IV. V. VI. VII. VIII. IX. X.
† See *Exp.* I.
‡ See Lect. I. §. 16.
‖ See §. 25, 26. & alibi paſſim.
** §. 27, 28.

naturally to make a conſtituent part of both *.

4. Hence may be conceived in general, how all the Changes happen in this great Chaos the Atmoſphere; *viz.* according as floating Particles of different kinds chance to meet, ſo as to form conſiderable Aggregates or Collections; and according as they are favoured by the requiſite Degree of Heat, Cold, Dryneſs or Moiſture. So, for example, a Cloud of nitrous Spirit, meeting with a Cloud of oily Particles, might ſuddenly produce Coruſcations, as in the mixing of Spirit of Nitre and an eſſential Oil †. And in this manner may the Generation and Phænomena of all the Meteors be chemically explained. And thus the occurſion of various Parts of different Bodies in the Atmoſphere may be the Cauſe of the Meteors, fiery Winds, Exploſions, Thunder, Lightning, the Aurora Borealis, and other Phænomena, which we can imitate by certain mixtures, in the way of Philoſophical Chemiſtry ‡.

5. That the Atmoſphere is an Univerſal Inſtrument, both in the hand of Nature and Art, for producing Effects, whether on the Surface of the Globe, in the Bowels of the Earth, in the Air itſelf, in the Laboratory, or in other human Works ‖. Thus it cauſes Fire to burn, and Bellows are but Engines to convey it thro' our Fires.

6. That as Air deſcends and acts more forcibly in the ſubterraneal Regions, than upon the Earth's Surface, on account of its greater denſity there,

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* §. 27, 28, 36, 37, 38.

† See *Exp.* I.

‡ See Mr. *Lemery*'s Philoſophical and Chemical Explanation of Subterraneous Fires, Earthquakes, Hurricanes, Thunder and Lightning, in the *French* Memoirs, *Anno* 1700.

‖ See the whole *Lecture paſſim*. See alſo *Lect.* I. *paſſim*.

there, and the ſubterraneal Heat; hence Vulcanos and more violent Fires may happen there, than upon the Earth's Surface *. And poſſibly this greater Heat and Power of the Air below, is neceſſary to the production of Minerals and Metals †.

7. Hence we may learn the Phyſical Cauſe, why diſtilled Aromatick Oils loſe their Native Spirit, grow thick, and terebinthinate in the open Air; why Wines grow flat, or loſe their briskneſs; why pale volatile Urinous Spirits grow red; why Mineral Waters loſe their virtue in the open Air; and how in all reſpects Air has a powerful Influence upon Liquors; as being a dry Fluid in briſk Motion, ſo as eaſily to lay hold of and carry off all the ſubtile and moſt moveable volatile parts of Fluids; leaving the groſſer behind, and thus changing the Texture, Colour and Conſiſtence thereof ‡.

8. That the Atmoſphere is, perhaps, the moſt compounded and diſſimilar Maſs in Nature; conſiſting of an Elaſtic part, and the Vapours and Exhalations ariſing from all the ſolid and fluid Bodies of the Globe, Salts, Oils, Minerals, Metals, *&c* ||.

9. That the Air is the cauſe of numerous Effects, ill aſcribed to other Cauſes by the ancient Chemiſts, who for want of the Air-Pump and other Contrivances, were ignorant of the genuine Properties and Effects of the Air **.

10. That the component parts of the Atmoſphere are coarſer than thoſe of Fire. For the com-



* See *Lect.* II.

† See above, *Exp.* X. See alſo the *Lecture* on Metallurgy hereafter.

‡ See *Exp.* I. VI. IX. & §. 18.

|| See *Exp.* I. *&c.*

**See *Exp.* VIII. IX. X.

component parts of the Atmoſphere will not paſs thro' Glaſs *, Stones, Metals, &c. as Fire does. Hence the Air may be artificially excluded from many Bodies †; and Water, Lixiviums, Oils, &c. paſs where Air cannot; as we ſee in Bladders, Wet-Leather of the Air-Pump, &c.

11. That the Atmoſphere is continually at work upon all the Bodies ſubject to its Power, in the way of a Menſtruum; whence Iron ſtanding in the open Air, is corroded; imperfect Glaſs diſſolved; Salts and Sugars run into Liquor; and the Bodies of Animals, Vegetables and Minerals prey'd upon ‖.

12. That there is a continual Reciprocation betwixt the Earth and the Atmoſphere; they mutually diſtilling, as it were, or precipitating matters from one into the other. Thus the Earth, by the Sun's Heat, ſublimes ſome parts of all things into the Atmoſphere, and the Atmoſphere again precipitates them to the Earth **.

13. That the different Succeſs of Chemical Operations may be greatly owing to the particular Vapours or Effluvia floating in the Laboratory; where ſuch Operations are performed ††. Thus if Salt of Tartar be run *per deliquium*, where Vinegar is diſtilling, it becomes regenerated Tartar; a thing very different from that intended.

14. As Air always adheres to the Surface of Bodies, and as the Surface of Bodies is enlarged by pulverizing ‖‖; when we would exclude Air in

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* See *Exp.* II. III. VII, VIII. IX.

† See *Exp.* II. III. VII. VIII. IX.

‖ See *Exp.* I. II. V. VI. VII. VIII. IX. See alſo below, *Ax.* 20.

** See *Exp.* I. & *Lect.* I. *paſſim.*

†† See *Exp.* I.

‖‖ See *Exp.* II.

n Chemical Operations, the Subject ſhould not be pulverized.

15. That the open Air has a powerful Efficacy, in many Chemical Operations; eſpecially n Mixture *, where it often acts mechanically by its Weight and Motion, as in the mixing of Oil of Turpentine with Salt of Tartar, which does not ſucceed *in vacuo*, or in high mountainous places.

16. That the Acceſs of Air is not neceſſary to certain Fermentations, or Ebullitions and Solutions; ſome of them proving more violent *in vacuo*, than in the open Air †.

17. That no Degree of Cold, or Condenſation, has hitherto been able to deprive Air of its fluidity, or render it conſiſtent ‖. If there were ſuch a Power exerted in Nature, it would deſtroy all Animals and Vegetables, and perhaps ſtop the growth of Minerals **.

18. By comparing the preſent Enquiry with the preceding; it appears that Fire cannot ſeparate Oil from Bodies, without the admiſſion of the free Air. Whence in the roaſting of ſulphureous Ores, or obtaining of white Aſhes from Bones or Vegetables, we are directed to uſe an open Air, as well as a naked Fire.

19. That the Air is in a kind of perpetual Motion ††. Whence it performs all thoſe natural Offices, that cannot be performed in a *Vacuum*. Thus leaven'd Paſte will not ferment or riſe; nor Wine work, nor Fleſh putrefy, nor Fruit corrupt, after the uſual manner, when placed *in vacuo*.

20.

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* See *Exp.* VIII.
† See *Exp.* IX.
‖ See *Exp.* IV.
** See *Exp.* VI. & X.
†† See *Exp.* I. & IV. See alſo, *Ax.* 12. & 17.

20. That as all kinds of Particles naturally float in the Air *, the Air may on this account act as an universal Menstruum; and in time dissolve any Body exposed to its action; because in tract of Time, the Particles capable of dissolving it must necessarily come at it †.

21. That many Arts may be assisted, or carried on to better advantage in some places than in others, by the means of certain Particles floating in the Air of one place more than another. Thus 'tis said that the Scarlet Dye is better struck at *Leyden*, than in other Places of *Holland*, where the Water and Atmosphere are impregnated with the Effluvia, Exhalations, or fine Particles of the Dye ‖.

23. Hence also we are directed to chuse proper Seats for Health, and Habitation, as well as for Operations and the Exercise of Arts **.

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* See *Exp.* I. & *alibi passim.*

† See *Ax.* II.

‖ See *Exp.* I. & *alibi passim.*

** There are various ways of trying the Wholesomeness or Unwholesomeness of Airs and Places; as by finding their Degree of Moisture several ways; by the Changes of Colour produced in white Linen, or stained Paper, left out in the Air; by exposing Copper-Plates, to shew the Colour of the Vitriol, that wou'd thus be made; and many other Expedients might be contriv'd for that purpose. [See Mr. *Boyle*'s Natural History of the Air.]

# LECTURE IV.

CONTAINING,

*The Solid or Earthy Matters of the Terreſtrial Globe, claſſed and examined, under* (1.) *Garden Earths*; (2.) *Bolar Earths*; (3.) *Saline Earths*; (4.) *Sulphureous Earths*; (5.) *Stony Earths*; *and* (6.) *Metallic Earths.*

*The Subject.*

1. WE now come to enquire into the Solid or Earthy Contents of the Globe; more particularly into the Parts concerned in Vegetation.

2. We ſhall begin with the Earth's Surface; and deſcend down gradually, ſo far as Men have hitherto dug.

*The Upper Coat of the Earth.*

3. The Earth's Surface is generally found covered with Verdure, or a Vegetable Coat, and in ſome places with Sand, Duſt or Mud.

4. Under this Superficial Coat, there uſually lies a Bed of Mould, or Underturf-Earth; of different depths, from one foot to two, three or more, in different places. (1.) This Mould, or Underturf-Earth, is the proper Matrix of Vegetables; and will come to be firſt examined in order.

*The Species of Earths.*

5. We ſhall next proceed to the other Species of Earths, that lie below, *viz.* (2.) the Bolar; (3.) the Saline; (4.) the Sulphureous; (5.) the Stony; and (6.) the Metallic. For under theſe ſix general Claſſes, we apprehend that all the Earthy

Earthy or Solid Matters of the Globe may be ranged.

6. It will therefore be our endeavour to give a general Example of the method of treating every Species; ſo as to diſcover their Natures, Offices and Uſes.

## EXPERIMENT I.

### *The farther Analyſis of Garden-Mould or Underturf-Earth by Water* *.

*Mould analyſed by Water.*

7. (1.) We took four pounds of freſh, black and crumbly Garden-Mould, eſteemed the beſt ſort; and what had lain, for a Year, expoſed to the Atmoſphere, and not been exhauſted in Vegetation.

(2.) This Mould we elixated, in fair and freſh boiling Water; till all that was capable of diſſolving therein was got out, or imbibed by the Water.

(3.) Having thus obtained a Lixivium or Solution of our Subject; we filtred it thro' thick doubled Paper, in order to obtain it tranſparent, and at leaſt free from any groſs terreſtrial parts, that might otherwiſe lodge therein.

(4.) This Solution therefore, contains all the parts of the Subject that are ſoluble in boiling Water †.

(5.) To bring theſe parts nearer together, that they might manifeſt themſelves to the Senſes, and particularly to the Taſte; we exhaled away the more aqueous Fluid in the form of Vapour.

(6.) Then comparing the concentrated Solution, with a portion of the former, that remained

* See *Lect.* I. *Exp.* I.
† See *Lect.* I. *Exp.* I.

mained unevaporated, we found it taſte manifeſtly ſtronger or more ſaline.

(7.) To gain a fuller Information, we evaporated a portion ſtill higher; and ſet it to cryſtallize, to ſee if any Salt wou'd ſhoot *.

(8.) To a part of the filtred Solution, we added Syrup of Violets, *&c.* to diſcover whether the Solution was acid, alkaline or neutral; and found it rather the latter †.

(9.) We waſhed the remaining terreſtrial Matter in ſeveral Waters, every time decanting the upper muddy Liquor, after a little ſtanding, in order to procure the pure Sand contained in the Mould; and found the Sand to be a large proportion of the whole.

8. This Experiment, or rather Combination of Experiments, ſhews us a method of reſolving the matrix Earth of Vegetables, into its conſtituent parts; without altering their natural Form and Properties. Whence it ſhould ſeem, that a true Judgment might be formed of Moulds, both in general and particular, ſo far as this Information reaches; and a Rule be obtained for their artificial Mixture or Compoſition. Thus we find the Mould under Examination contains a certain proportion of fine Earth, capable of being ſuſpended in Water; much more of a groſſer heavier part that readily ſinks in Water; perhaps a little neutral Salt; and a large proportion of Sand. Hence if this Mould had come from the Iſland *Ceylon*, for inſtance, and there ſerved for the growth of Cinnamon; we might be directed by this Analyſis, to make or mix up a Mould that ſhould reſemble it, for producing Cinnamon in *England*.

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* The Succeſs was not carefully noted.

† See the Method of examining *Mineral Waters*, in the following *Lecture*.

*England.* But to render the Experiment ſucceſsful, no leſs regard muſt be had to the State and Ingredients of the Atmoſphere, than to the State and Ingredients of the Soil *.

9. To render the preſent Experiment more inſtructive, and uſeful, for diſcovering the Principle of Vegetation, and the Nature of Earths and Plants; it were proper to compare it with a ſimilar Analyſis of certain Vegetable Subjects. Thus by bruiſing a tender Plant, elixating all its ſoluble Parts with warm Water, exhaling the ſuperfluous Moiſture, and ſetting the remainder to cryſtallize, we obtain the native ſaline part of the Plant, in the form of a ſolid Salt, which appears either of the tartareous or nitrous kind, according to the Nature of the Plant †.

10. And tho' any Alkaline Plant, as Creſſes, were watered in its growth with a Solution of Nitre, which upon Diſtillation affords much acid Spirit; the Plant would ſtill prove alkaline: and the ſame holds of every Plant and Salt hitherto tried ‖. Whence there appears to be a power in Plants, of changing any other Salt into their own. And hence we find, upon Experience, that Compoſts abounding in Sea-Salt, Nitre, or urinous Salts; all agree to promote Vegetation.

11. But as there may be certain more fixed parts naturally contained in Mould, than will diſſolve in boiling Water; and as theſe parts may poſſibly be looſened, digeſted and rendred capable of aſcending into Vegetables, by the long-

* See *Lect.* III.

† See M. *Homberg*'s Paper upon the Nature of Vegetable Salts. *Memoir. de l'Acad. An.* 1699.

‖ I could wiſh the Experiment tried with Sugar, Alum, Pot-Aſh, *&c.* both in Alkaline and acid Vegetables. But Care ſhould be taken, not to uſe too much of the Salts; which wou'd deſtroy the Nature of Mould.

long-continued Action of the Sun and Atmosphere; it may be proper to try a more powerful Analysis of the same Subject.

## Experiment II.

### *The Analysis of Garden-Mould by Fire.*

12. Having weigh'd two pounds of the same kind of Virgin-Mould as in the preceding Experiment, we put it into an Earthern Retort; and committed it to a naked Fire, working by slow Degrees of Heat into a Glass-Receiver; at last keeping the Retort ignited, for some time. There came over (1.) a Water; (2.) an Oil; and (3.) a volatile Spirit almost like Spirit of Hartshorn, or as if the Subject had been Animal *; and (4.) there remained behind a dry *Caput Mortuum*, or apparently fixed and indolent Earth. *By Fire.*

13. We elixated part of the *Caput Mortuum*, and then dried it, and by Triture reduced another Part into one similar, homogeneous Powder; with a design to put each Parcel into a separate Pot, and expose them to the open Air, for a Year, to try whether they wou'd then prove fertile.

14. It appears by this Experiment, that our Garden-Mould was of a Vegetable or Animal Nature, in respect of the Salts or Juices it contained; and only Mineral, with regard to its fixed Matter. In both which respects, it greatly resembles the Natural Composition of Animals and Vegetables. And hence we see the Physical Reason, why Animal and Vegetable Substances are

* If it be supposed, that the Compost which might have been used to this Mould, was not sufficiently rotted or changed; so as still to retain its own Vegetable or Animal Nature: let the Experiment be repeated with Earth, which has been known to have lain several Years fallow.

are proper Compoſts for Land. If we were to enquire how Mould comes to be of this nature, it might in good meaſure appear from our former Doctrine of the Natural Contents of the Atmoſphere; which being Animal and Vegetable, as well as Mineral, continually fall upon the Surface of the Earth. And hence it manifeſtly is, that Gardeners find a difference in the Soil of *London*, from that of open Country Places; on account of the quantity of Smoke daily precipitated out of the Air, upon the Gardens of *London*. And the like is to be underſtood of other Cities and Countries reſpectively.

15. By comparing the preſent Proceſs with the ſame performed upon a Vegetable, an Animal, and a Mineral Subſtance; it appears, that one ſimple *fixed Earth* is the Baſis of all Animal, Vegetable, Mineral and Earthy Matters; or the true *Stamen*, Support and Skeleton of Fleſh, Bone, Wood, Metals, and Earths, *&c.* being in itſelf of a fixed unalterable nature.

16. We next proceed to *Bolar Earths*; which ſeem diviſible into two Species, according as they are more or leſs tenacious; in which view *Loam* and *Clay* may repreſent them all. And even theſe two ſeem only to differ in reſpect of the fineneſs or coarſeneſs of their component Parts; which renders them more or leſs tenacious, clinging or adheſive.

## EXPERIMENT III.

*That Fineneſs of Parts in Earths, may give Coheſion, Strength and Solidity.*

*Loam made into Clay.*

17. (1.) We mixed common Loam into a Maſs with Water; then dry'd it; to ſhew that compared with Clay, it would eaſily break, crumble and fall into Powder. But (2.) beating ſom

ſome Loam fine in a Mortar, and mixing it well with Water, it clung like Clay; and when dry'd, adhered much more tenaciouſly than before.

18. This Experiment not only ſhews that Loam and Clay, or all the Bolar Earths, are nearly the ſame thing, when their component Parts, or gravelly and ſandy Matters, are reduced to the ſame Degree of fineneſs; but alſo ſupplies us with a Rule for the Improvement of Pottery, and the Imitation of *China* Ware. This Rule is to grind, or beat, the Earths employed, to an extreme degree of fineneſs; and accordingly Porcellane has been imitated in *Europe*, by Tobacco-Pipe Clay, and other Earths exceedingly fine ground; mixed into a Paſte with Water, and properly dried or baked. *Pottery hence improveable.*

19. The ſame Experiment may likewiſe inform us how Rocks are often produced, of different Degrees of hardneſs; according to the different fineneſs of the terreſtrial Particles depoſited upon any Eminence, or Declivity, as waſhed down by the Waters. *Farther Uſes of the Experiment.*

20. We recommend it to future Examination, how far this Mechanical Tenuity of Parts may reach, in cauſing Strength and Hardneſs in Bodies: and whether thoſe two Properties are not different in Glaſs, Cryſtal, Diamonds, *&c.* on account of the different fineneſs of their Parts *.

21. Under this Tribe of Bolar Earths, we rank all the hungry Garden-Earths, all the ſandy Field-Earths, all the Clay or Marly Earths; and all the mixtures hereof. *Bolar Earths what.*

22. We next proceed to Saline Earths; by which are meant all thoſe wherein any quantity of Acid, Alkaline or Neutral Salt is evidently contained. *Saline Earths.*



* See Mr. *Boyle* on Gems.

23. If ſtrict examination were made, perhaps no Earth would be found without ſome proportion of Salt; which has pretty generally been thought the Principle that holds all Earths together. And there appears ſome Reaſon for the Opinion, as we endeavoured to ſhew by the following Experiment.

## EXPERIMENT IV.

*That a Saline Matter may give tenacity and firmneſs to Earth.*

*Quick-lime deprived of its Salt.*

24. (1.) We ſlaked Quick-lime with a ſufficient quantity of Water to bring it into a kind of Paſte; (2.) Then ſuffered the ſuperfluous Moiſture to exhale gradually. Upon which, (3.) the Lime acquired a ſtony Hardneſs. (4.) We next poured a much larger quantity of Water, upon another parcel of Quick-lime than ſufficed to make it into a Paſte; then decanted the Water, which taſted manifeſtly ſaline. And (5.) we afterwards elixated the remaining Matter with ſeveral parcels of freſh Water, to get out all the Salt of the Lime. (6.) And now drying the Calx thus deprived of its Salt, we found it would not hold firmly together, but remained perfectly crumbly or duſty.

*Uſes of the Experiment.*

25. This Experiment ſhews us the Nature and Compoſition of Lime, which, mixed with Sand, makes the common Mortar uſed in Building. We ſee it is the Alkaline Salt contained in the Lime, and either extricated or produced in calcining the Lime-ſtone; that occaſions the Mortar to concrete and harden. And where the Salt is in its full proportion, the Lime is ſtrongeſt and the Mortar hardeſt and moſt durable. This ſaline Principle it alſo is in Lime, which gives it the advantages over Chalk, as a Compoſt for

Grounds

Grounds, exhauſted or drained of their natural Salt in Vegetation. For the Alkaline Salt of the Lime, by ſtrongly attracting the Moiſture of the Atmoſphere, and other Particles that float therein, thus ſwells, dilates, crumbles and opens the Earth wherein it is mixed; whence the Atmoſphere has the freer action thereon; and in the mean time the Alkaline Salt of the Lime becomes of a neutral, or nitrous fertilizing Nature.

*The Claſs of Saline Earths.*

26. Under the general Head of Saline Earths, may be reckoned all thoſe that are calcined, or burnt in the Fire; as all the kinds of Lime, Potaſh, Salt of Tartar, Soot, *&c.* theſe being but mixtures of Salt and Earth: and to ſay the truth, all Salts appear upon a rigorous examination to be no other than Earths of different Natures; which, when reduced to a certain Degree of Subtilty, or Fineneſs of Parts, ſo as permanently to diſſolve in Water, are then emphatically denominated Salts.

*Sulphureous Earths.*

27. The following Experiment regards the Sulphureous Earths; under which we reckon all thoſe that will flame in the Fire; as Coal, Bitumen, Sulphur, certain crude Ores, Marcaſites, *&c.*

*Marcaſites what.*

28. By Marcaſites we underſtand all thoſe Mineral, Earthy and Sulphureous Matters, that are otherwiſe called *Pyrites*, Fire-Stones, Braſs-Lumps, Mundicks, or the like. For tho' theſe may be diſtinguiſhed in reſpect of leſſer differences; yet in general they are all a Compoſition of Sulphur, un-inflammable Earth, and a ſmall proportion of Metal.

## EXPERIMENT V.

### *The Analyſis of ſulphureous Earths by an Example in Mundick.*

*Mundick analyſed.*

29. We took half a pound of Mundick, reduced to fine Powder, and put it into an Earthen Retort; which being placed in a naked Fire, we fitted on a capacious Glaſs-Receiver, and luteing the Juncture well with a mixture of Loam and Horſe-dung, we gave Degrees of Fire, up to the ſtrongeſt; then let all cool, and took off: we found a ſmall proportion of an acid Liquor, exactly like the Spirit of Sulphur, made by the Bell, at the bottom of the Receiver; and a conſiderable quantity of Flowers of Sulphur ſublimed to the top.

30. The *Caput Mortuum* being taken out, and flux'd with half its weight of clean Iron Filings, afforded a little Lump of a Metallic Subſtance, or *Regulus*.

*Uſes of the Experiment.*

31. Hence we ſee that Marcaſites chiefly reſolve into Sulphur, and a more fixed earthy part; which being treated as an Ore, yields a proportion of Metal. And hence perhaps all the Pyrites, Braſs-Lumps, Marcaſites and Mundicks are but cruder kinds of Ore; and if they cou'd be brought to full maturity, they would prove real Ores.

*Marcaſites firing.*

32. Theſe Marcaſites, upon long lying in the open Air, attract the Moiſture thereof; and thence grow hot, in ſome meaſure diſſolve, form an efflorescence on their Surface, and by degrees turn into a Vitriol, of the ſame kind with the Metal they contain. Thus if that Metal were Iron, the Vitriol becomes green or martial; if Copper, blue or cupereous. And on this is

founded

founded the Artificial Method of making Vitriol, now practiſed in ſeveral parts of *England*.

33. And from the heating, fuming and firing of theſe Sulphureous Earths, by the Moiſture of the Air, we may perhaps learn the Origin of Hot Baths, Mineral Waters, Damps and Fires in Mines. For it is found, that a Pile of theſe Sulphureous Earths, being barely moiſten'd, will at firſt ſmoke, and at length take fire, and burn like glowing Coals *. *Whence Hot Baths, Damps and Fires in Mines, &c.*

34. Our preſent Experiment likewiſe ſhews us a way of examining theſe Marcaſites, (which have been frequently taken for rich Ores, both in *England* and elſewhere) and of extracting the Metal they may hold; after having firſt ſeparated their Sulphur. Many ſkilful Metalliſts have been impoſed upon by the ſpecious ſhew of theſe Marcaſites; for they uſually have a great ſpecific Gravity; and ſome of them a greater than real Ores: whence again they may poſſibly contain the Matter of Metals, tho' in a crude, imperfect or unfixed ſtate. But to bring this matter to the Teſt, or try the validity thereof, requires a more than common knowledge in Metallurgy †. *How examined for their Metal.*

Our next Species of Earths is the Stony. *Stony Earths.*

## Experiment VI.

*That Ignition may deſtroy the Tenacity or Coheſion of Stony Earths, ſhewn in Alabaſter.*

35. (1.) We reduced two Pounds of ſoft Alabaſter to fine Powder; then put it into a flat Iron Pan, *Alabaſter calcin'd.*



* See Dr. *Power*'s Experiments, *page* 63.

† A ſmall proportion of Silver has been obtained from certain kinds of Mundick; after the Mundick had been flux'd with Iron-Filings, and brought to a Regulus.

Pan, and apply'd a ſoft Heat, that the matter may not glow; yet remain too hot to be touch'd. The Powder was thus brought to flow or run like Quickſilver; and being gently ſtirred, to boil and bubble. We let it continue thus, with a ſoft heat, till it would run off a Spatula held almoſt horizontal; then removing it from the Fire, it grew cold, and was put into a Glaſs, kept cloſe ſtopped, and ſet in a dry place, under the name of *Gypſum*, or calcin'd Alabaſter.

(2.) A parcel of the *Gypſum* thus prepared, being brought into a pappy conſiſtence with Water, the humid Maſs became ſo hard and rigid, in a quarter of an hour, as to ring, or afford a clear Sound, when ſtruck with the Finger, or any more ſolid Inſtrument.

(3.) But a parcel of the ſame Powder kept in a ſtate of Ignition for ſome time, before it was taken out of the calcining Pan; being mixed with Water, it acquired only a looſe, friable conſiſtence, or a much leſs Degree of hardneſs and tenacity than the other. The un-ignited ſort alſo, by being kept in the open Air, loſes of its coagulating Virtue; and when once conſolidated with Water, becomes unfit for the like purpoſe again.

*Uſes of the Experiment.*

36. Thus all the Stony Earths that do not vitrify in the Fire, are by Ignition reduced to fine Powder. So may Flints themſelves, by being often ignited and quenched in Water. And thus White or Cryſtal Marble is reduced to a Powder, fit for the making of pure white Glaſs.

37. This Experiment alſo ſhews us an earthy Matter, apparently fluid over the Fire, that will harden in Water; and ſerve to direct a farther enquiry after cheap Bodies, that will grow ſtill harder under water: which might be of

ſervice

ſervice in Bridge-works, Water-works, and the like *.

38. The preſent uſe of the Preparation is ſufficiently known; for taking off Faces, Impreſſions and Figures; and the ſtopping of leaky Pipes or Veſſels, that tranſmit or contain Water.

39. The ſixth Claſs is that of *Metallic Earths*. For there are ſome Reaſons to judge, that even Metals themſelves are but a Species of Earths †; as they both burn into Aſhes; and melt into Glaſs: whilſt their metallic ductile Form appears owing to nothing more than a certain proportion of Sulphur, or Oil they contain; which when burnt out, leaves them terreſtrial Calces, or certain Metallic Earths, of a nature peculiar to each Metal ‡. *Metallic Earths.*

40. And thus we may divide Earths into two general Tribes, *viz.* the *Brittle* or *Friable*, and the Ductile or Malleable. We have gone thro' the Friable Species; and ſhall proſecute the Ductile hereafter, in our Lecture upon *Minerology and Metallurgy*. *Earths reduced to two general kinds.*

## Axioms *and* Canons.

1. We learn from the foregoing Enquiries, that the Atmoſphere, with its Contents, is a chief Inſtrument in promoting the Fertilization of the Earth, whereby all Vegetables, and thence all Animals are fed, ſupported and maintained ‖; that this Mould may in ſome meaſure be ſup-



* See Mr. *Boyle's* Philoſophical Works, Abridg. Vol. I. *pag.* 330, 331.

† See *Becher's Phyſica Subterranea* paſſim.

‡ See *Stahl's* Comment on *Becher's Phyſica Subterranea*; *& alibi paſſim.*

‖ See *Lect.* III. *paſſim.* See alſo the preſent *Lect. Exp.* I. II.

plied by the Air, at different times *, and afterwards by lying immediately under the Turf, receives whatever richneſs or fine matter deſcends from above, in the form of Dews, Rains, Snow, Hail, or other more ſubtle Conveyance: and that this invigorating Subſtance ſoaking thro' the upper Turf, may be thereby defended from the Winds and beating Sun, as by a Skreen, from being exhaled too ſoon again. And thus the Atmoſphere exerciſes a kind of renovating Power; ſo as to ſupply even exhauſted Earths with freſh Vigour; and fit them for the production of new Crops †. Whence we have a good Rule for renovating and recruiting ſhrunk, withered and exhauſted Vegetables, by expoſing them to a kindly Atmoſphere, rather than by bare watering them; which might only ſerve to corrupt and ſpoil them the ſooner.

2. That ſome capital Rules may be formed for the Improvement of Agriculture, Horticulture, and the raiſing and improving of Fruit and Foreſt-Trees; by finding the Nature, Compoſition and Ingredients of the Soil, wherein each kind of Grain, Plant and Tree, is moſt delighted ‖.

3. That it is poſſible, by rational Experiments, to find the beſt kinds of Steepings for Grain and Seed, and the beſt kinds of Compoſts and Manure for Land; according to the Nature, or preſent Exigence of the Soil, or the Fruit intended to be produced; or any one particular Salt, Oil or Property to be introduced; either into the Ground or Seed **.

4.

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* See *Lect.* III.

† See *Lect.* III. and the preſent, under *Exp.* I. & II.

‖ See *Exp.* I. & II.

** See *Exp.* I. & II.

4. That Water, as well as Fire, may be an uſeful Chemical Analyſer in ſome caſes *.

5. That all Vegetable and Animal Subſtances, Excrements, *&c.* naturally change and become Compoſt, and at length Mould; whence there is a continual Reciprocation between the Animal and Vegetable Kingdoms: which thus continually paſs into one another, by the Mediation of the Atmoſphere, Heat, and other natural Agents †.

6. That Compoſts, before they can produce their Effect, muſt in ſome degree approach the Nature of the Soil they are deſign'd to improve ‡.

7. That by Earths are underſtood ſuch groſs Subſtances, as are of themſelves inſoluble in Water, and indeſtructible in the Fire; yet with fixed Alkali melt into Glaſs; or with any unctuous Matter aſſume the form of a Metal; according to their reſpective Natures ‖: and conſequently, that even Earths, tho' apparently exhauſted ſimple Bodies, have yet their reſpective or peculiar Properties and Effects **.

8. That the moſt fixed part of Earth has many Inſtrumental Efficacies; not only as floating in the Air, and as forming the Bed or Matrix of Vegetables; but alſo in conſtituting the ſolid Parts or Stamina of all Vegetable, Animal and Mineral Subſtances ††; and affording us all our Veſſels of Glaſs, Stone, Wood, Metal, our Furnaces, Crucibles and Teſts,

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* See *Exp.* I.
† See *Lect.* III. & *Exp.* I. II. of the preſent
‡ See *Exp.* I. & II.
‖ See all the *Experiments*.
** See above §. 5, 26, 38.
†† See *Exp.* I. II. *&c.*

Teſts, and being perhaps in itſelf the moſt fixed and unchangeable Body in Nature *.

9. That a high Degree of Trituration, or reducing the Particles of certain Bolar Earths, Clays and ſtony Earths, to an extreme fineneſs, may contribute to the Improvement of the Art of Pottery. For which purpoſe, Trituration, Sifting, Subſidence in Water, and Decantation, might be uſed to advantage †.

10. That the making of Lime may be improved, for the purpoſes of Buildings, Manure and Water-works; by a due choice of the Materials, and a ſuitable Calcination ‡.

11. That ſome conſiderable Uſe and Improvement, might, with proper Skill and Application, be made in the buſineſs of Marcaſites and Mundicks; Bodies uſually eſteemed as Refuſe, and intractable Stuff ‖.

12. That Marcaſites, by attracting the Moiſture of the Air, may be the efficient cauſe of ſubterraneal Fires, hot Springs, Damps in Mines, Mineral Waters, *&c* **.

13. That the Matter of Metals may poſſibly lie looſe, immature or unconcocted in certain Mineral Matters; ſo as in the Fire to fly away with the Sulphur, or other parts of the Mineral; unleſs detained, and brought to greater perfection either by Nature or Art ††.

14. That Fire may have the ſame Effect as Air or Time, on certain ſtony Matters, and make them looſe, crumbly and incoherent ‖‖.

LEC-

* See §. 15.
† See *Exp.* III.
‡ See *Exp.* IV. §. 25. *Exp.* VI. §. 36.
‖ *Exp.* V.
** See *Exp.* V.
†† *Exp.* V.
‖‖ *Exp.* VI. & §. 35.

# LECTURE V.

## CONTAINING,

## *A Natural and Chemical Examination of Waters.*

1. OUR preſent buſineſs is the Chemical Examination of Waters; with a view to manifeſt their Natures, their Uſes to the Earth, and all Vegetable, Animal and Mineral Subſtances; but particularly to Man, ſo far as we can diſcover them. *The Subject.*

2. By the general name of Water we underſtand an extremely fluid, limpid, inſipid, and inodorous Liquor. This Definition is obvious, and taken from the direct Teſtimony of the Senſes; but to enquire Philoſophically into the Nature of Water, we ſhall find it poſſeſſed of many unexpected Properties. *Water defined.*

### EXPERIMENT I.

*That Water is contained in many ſolid, and, to appearance, dry Bodies.*

3. We took a piece of the hardeſt and dryeſt Bone we could procure; and diſtilling it in an Earthen Retort with Degrees of Fire, obtained a very large proportion of Water; along with much Oil, and volatile Salt *. *Found in dry Bones.*

4.

* See this Experiment farther proſecuted in *Lect.* VIII. *Exp.* II.

4. This Experiment holds true even of the oldeſt Hartſhorn, the dryeſt and hardeſt Woods, Earths and pulverized Stones. Whence it appears, that Water may lie concealed in ſolid Bodies, and make a conſtituent part thereof; as we formerly ſhewed of Air *. For we do not here mean, that Water inſinuates itſelf into the ſuperficial Pores of Bodies; ſuch as Wood, Skins, Leather, Parchment, Strings, &c. ſo as to ſwell them in moiſt Weather, and leave them ſhrunk in dry: but that it remains permanently intermixed as an eſſential Ingredient, or as a part of ſolid Bodies; as in Stone or Brick after baking, &c. Of which we gave an eminent Inſtance in our laſt Lecture †, where we ſhew'd that *Gypſum*, with Water, preſently concreted to a ſtony hardneſs.

5. If any doubt ſhould ariſe, whether the Liquor obtained from the Bone in our Experiment be truly aqueous; we might ſhew it to ſatisfaction, by ſeparating the Oil, and turning all the volatile Salt contained therein, to Sal-Ammoniac; by means of a ſufficient quantity of Spirit of Sea-Salt; then rectifying the Liquor by repeated Diſtillation, and bringing it over in form of a pellucid, inſipid and inodorous Fluid ‖.

6.

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* *Lect.* III. *Exp.* X.

† *Exp.* VI.

‖ To purify this Liquor abſolutely, is a very laborious Task: but as ſome of the firſt Drops come over limpid, and almoſt inſipid, before the Oil and Salt begin to riſe; this may afford a ſtrong ſuſpicion, that the ſucceeding Drops are alſo aqueous; only mix'd with Oil and volatile Salt. For tho' the Bone were ever ſo thoroughly dried by the Fire; and the Veſſels employ'd ever ſo free from Moiſture; a large proportion of the aqueous Liquor would ſtill be obtained. Beſides, the foul and fetid Liquor has been ſo far cleared from the volatile Salt and Oil, as to appear limpid, and prove inſi-

pid

6. It is therefore certain, that all Vegetables, and even the moſt ſolid Parts of Animals, naturally contain a large proportion of aqueous Fluid, or actual Water, in their Compoſition; and that it remains in them unaltered in its own Nature; ſo as, when ſet free, to reſume the form of Water, after having been detained, or circulated therein for numerous Years. Whence it ſhould ſeem, that Water paſſes thro' all Natural Bodies, unchanged either by Accretion, Growth, Appoſition, Fermentation, Putrefaction, Digeſtion, Diſtillation, *&c.* being chemically recoverable again from Vegetables and Animals, Wines, Vinegars, and Spirits.

## Experiment II.

### *That Water may be collected from the dryeſt Air, or in the hotteſt Climate.*

7. (1.) We put half a pint of common Water into a cylindrical Glaſs, wiped perfectly dry on the outſide; then added to the Water, two Ounces and three quarters of pulverized and dry Sal-Ammoniac. We now ſtirr'd them briſkly together; whereupon the Water floating in the external Air, was, by the Coldneſs thus produced, condenſed on the outſide of the Glaſs, as the Salt diſſolved within, and trickled down in ſmall Veins into the ſhallow Baſon ſet underneath to receive it. *In the dryeſt Air.*

8.

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pid, and inodorous. And as it approached nearer to common Water, after every Rectification; there is no doubt but, if a ſufficient quantity were procured, it might by degrees be brought exactly to reſemble common Water, diſtilled and treated in the ſame manner. But the eaſieſt way is to impregnate common Water with the Oil and Salt of the Bone; ſo as to make it reſemble the Mixture that comes from the Bone into the Receiver upon Diſtillation. See more to this purpoſe in *Lect.* VIII. *Exp.* I. §. 14.

*The Experiment extended and applied.*

8. This Experiment holds in all Climates and Places, of different heights, where it has been tried. Whence, by the Law of Induction, we may make it univerſal, till any contradictory Inſtance appears. Thus therefore it may hold in the moſt parched Countries and hotteſt Seaſons; ſo as to afford an agreeable method of cooling potable Liquors; and rendring them more refreſhing. For if the containing Glaſs of the Salt and Water, be ſet in any Liquor; the Liquor will be cooled thereby, as the Salt diſſolves. And if any conſiderable Improvement could be made in the contrivance, it might ſerve in ſome meaſure to ſupply the thirſty Traveller in parched Deſarts; and Sailors with freſh Water at Sea; where it has been a practice to hang out Fleeces of Wool at the ſides of the Ship ov night, and to ſqueeze freſh Water out of them in the Morning.

9. The ſame Experiment being carried higher; affords us a Method of procuring a Degree of freezing Cold, in the hotteſt Countries, at all Seaſons of the Year. For if a quantity of dry and pulverized Sal-Ammoniac be ſeparately included in one well-cloſed Glaſs; and a proper quantity of common Water in another; and both theſe Glaſſes be put into the firſt Solution, whilſt the Salt is diſſolving; both the confined Salt and Water will ſoon acquire the ſame Degree of Coldneſs, as the firſt Solution: and being then taken out, and mix'd together, they will form a ſecond Solution much colder than the firſt. And thus by repeating the Experiment twice or thrice, with freſh Salt and Water, a Degree of freezing Cold may be ſoon obtained in the hotteſt Climate.

## Experiment III.

*That an Earthy Subſtance is naturally contained in Water.*

10. (1.) We filled three ſeveral Glaſſes with pure Rain-Water, Spring-Water, and *Thames*-Water; and let them ſtand cloſe covered, for ſome days before they were exhibited: there was an earthy Sediment then depoſited in all three; but moſt in the *Thames*-Water; the Sediment whereof was not only larger, but alſo more foul and muddy than in the Rain-Water; tho' here alſo it was dirty, perhaps becauſe not carefully collected: whereas in the Pump-Water, it was white, ſcaly, flaky and ſhining like fine Spangles of Talc. *Water contains Earth.*

11. This Experiment alſo is univerſal, ſo far as it has been tried with Care; and holds true of the Waters of all Species and all Countries; particularly in thoſe called Mineral Waters, from which an earthy Subſtance may uſually be precipitated by Art, in a conſiderable proportion. For example, by the bare addition of Salt of Tartar.

12. Certain Experiments carefully made, and repeated, ſhew that the terreſtrial Matter naturally contained in Water, has a principal ſhare in the growth and increaſe of Vegetables; all the Plants that thrive in Water, appearing to enlarge their Bulk, in proportion to the earthy matter they draw from the Water. Whence pure Elementary Water ſeems but a kind of Vehicle to convey this nutrimental or ſubſtantial part, and depoſite it in the Veſſels, through which the Water moves, in order to its general exit at the Surface of Vegetables *. But we are not here to

* See Dr. *Woodward*'s Experiments to this purpoſe, in the *Philoſophical Tranſactions*.

to exclude the Inſtrumental Efficacy of the two other Elements, Fire and Air. And this appearing to be the general Office of Water, in the whole Vegetable and Animal Kingdoms, *viz.* the conveyance or diſtribution of the alimentary Matter to all their parts; it may be proper to conſider its Phyſical Properties; which wonderfully fit it for this Office.

*Office and Uſe of Water.*

*Its Properties.*

13. The figure of its component Parts appears to be ſmooth and ſpherical, like thoſe of Quickſilver, whence it becomes extremely moving and penetrating. Thus it readily enters the Pores of Wood, Leather, Skins, Chords, Muſical Strings, *&c.* and thus it likewiſe becomes capable of moving, and agitating Particles of Matter leſs active than itſelf, and ſo proves the more immediate Phyſical Agent of Fermentation, Putrefaction, Solution, *&c.* And thus it alſo conveys earthy and ſaline Matters thro' our Filtres of Paper, Stone, *&c.* and even raiſes ſome proportion of them in Diſtillations.

14. Its Particles likewiſe appear to be extremely minute, and ſo have a large ſhare of Surface. Hence Water is admirably fitted for a Solvent, or for readily entring the Pores of Salts; and coming into full contact with all their Particles. And thus it will paſs where Air cannot, on account of its Moiſture, or lubricating Power; whereby it ſoftens mucilaginous matters, and will therefore ſoak thro' the cloſe Pores of a Bladder. And being thus qualified, it ſeems extremely well fitted to enter or ſlide thro' the fine Canals and Veſſels of Plants; ſo as to convey nutritious, ſaline or earthy Particles along with itſelf; and having depoſited them by the way, and being now robbed of all that is uſeful to the Individuals, it at length perſpires into the open Atmoſphere, in order to be there recruited and

fitted

fitted for fresh service. And the same kind of Office it performs in Animal Bodies.

15. Hence we may learn the physical reason why River-water is more fertilizing than Rain ; *viz.* on account of its containing more earthy Matter: and why such Meadow and Pasture Lands as lie commodious to be overflowed by muddy Rivers, yield greater Crops, than such as are watred by other means. And hence the incredible fertility of *Egypt*, appears to proceed from the turbid overflowing of the *Nile* ; and the same is to be understood of other Rivers in proportion ; as the *Ganges*, the *Thames*, &c *;

*That of Rivers why most fertilizing.*

## Experiment IV.

*That Water saturated with one Body will still dissolve another.*

16. (1.) We took four Ounces of pure cold Rain-water, and dissolved therein as much dry common Salt, reduced to Powder, as it would receive. The Salt being taken from a known quantity, we weighed the remainder, to find the precise quantity employ'd, and found it about an Ounce ; which therefore gave the measure of the Power that the Water had to dissolve common Salt, with the degree of Heat then present in the Atmosphere. To this saturated Solution of Sea-Salt, we added about two Scruples of dry pulverized Nitre ; and found that it was dissolved therein ; tho' no more common Salt could be taken up by the Water.

*The dissolving Power of Water.*

17. This Experiment is only particular ; for the dissolving Power of Water is different in



* See *Boyle*'s Abridgment, Vol. I. *pag.* 248, *&c.* and *Lowthorp*'s Abridgment of the Philosophical Transactions, Vol. II. *pag.* 725, *&c.*

different Subjects *. Whence a Set of Experiments ſhould be made, to ſhew this Power in all the Salts, and other Subjects, whether mucilaginous, gummy, earthy or others, that are capable of diſſolving in Water. Such a Set of Experiments might prove of conſiderable uſe, in Phyſical and Chemical Enquiries; and help to rectify the Mind, which is extremely apt to form general Rules from a few particular Inſtances. Whence Water has often paſſed for a kind of Univerſal Solvent; tho' there are numerous Bodies which it will not diſſolve †. And from this erroneous Notion of a general diſſolving Power in Water, the Enquiry into Mineral Waters has in great meaſure either been ſtopped, or perverted ‖.

18. The limited Power which Water has, o diſſolving common Salt, appears remarkably in the Ocean; which we ſee, by our Experiment may naturally contain about one fourth part o ſuch Salt; or, with an additional Heat, conſide rably more: tho' its charge is always limited by the Nature of the Thing; and cannot be abov one certain proportion. Which, however, i found to differ in different Seas, or Bays; th Water of ſome being found to yield more Sal than others: according to the greater Heat or Ex halation of Vapor in thoſe Seas or Bays; or a gain, perhaps, according to the opportunity whic the Water has had of running upon a more ſalin Bottom, &c.

19. But when Water has diſſolved its fu proportion of common Salt; we ſee, by th Exper

* As will appear hereafter, *Lect.* VI. *Exp.* I.

† As Stones, Metals, Glaſs, Gems, Amber, Shells, Cor Sponge, Cloth, &c. See hereafter *Lect.* VI. §. 15.

‖ See the *Appendix* to *New Experiments and Obſervatio* upon *Mineral Waters*, lately publiſhed.

Experiment, that it may ſtill diſſolve in Water ſome quantity of another Salt. And how far this Power may extend, as to the matters at the ſame time diſſolvable in Water, has not been hitherto ſufficiently aſcertained *.

20. Nor is the Method wherein different Salts range themſelves in the ſame Water, preciſely determined. That they do not intermix, ſo as inextricably to entangle and confound their Particles among one another, appears from Cryſtallization. For if ſeveral different Salts be diſſolv'd together in the ſame parcel of Water; they may be made to ſhoot ſeparately out of it again, by repeated Evaporation and Cryſtallization; each in its own natural form and figure, or pure and unmixed with the reſt. But the Power of Water as a Solvent, will again come to be conſidered in our next *Lecture upon Menſtruums* †.

## Experiment V.

### *The natural Ingredients or different component Parts of Water.*

*The Contents of Water.*

21. (1.) We took a Pint of the pureſt Rain-Water, decanted from its natural Sediment; and put it into a bellied Glaſs, with a long ſlender Stem; then marked the part of the Stem whereto the Water roſe, and ſet it in the exhauſted Receiver, where we found it manifeſtly expanded, and diſcharged many Bubbles of Air. (2.) We put the ſame Water into a clean Glaſs Retort; and diſtilling with a gentle Heat into a Glaſs-Receiver, there came over a pure light Water, or merely aqueous Liquor; leaving a



* See Dr. *Grew* and Mr. *Boyle paſſim*.
† See *Lect.* VI. *Exp.* I.

ſmall quantity of dry and whitiſh terreſtrial Matter behind.

22. This Experiment requires a farther, and much more exact proſecution. We ſee it reſolves Water into three diſtinct, and, to appearance, different Parts; *viz.* (1.) Air, (2.) Elementary Water, and (3.) Earth. The truth of this Analyſis ſeems confirmed by other Experiments. For Water, by boiling, is alſo deprived of the Air it naturally contains. And ſo it likewiſe is by ſtrong freezing; the Ice being thus, by degrees, made leſs porous, and purged of its Air-Bubbles: And Water always upon thawing leaves a quantity of earthy Sediment behind. But neither this Experiment of freezing and thawing, nor the re-diſtillation of Water, has been carried ſo far as to ſhew, with certainty, whether any, and what proportion of the Water, is thus actually convertible into Earth; or whether a quantity of earthy Matter, before diſſolved or finely diſperſed in the Water, is thus only aggregated, or collected together, and left behind, in a dry, ſolid, or earthy form, upon Evaporation.

23. The determination hereof is of conſequence to Phyſicks: The Circumſtances that tend to invalidate the Experiment by Diſtillation, are, (1.) That the Water ſuffers a great diminution of its quantity in the Operation; ſome part ſticking to the ſides of the Veſſels employed every time; and ſome tranſuding thro' the Luting. Whence the account is defrauded. And (2.) that in tranſvaſing the Liquor, it every time licks up the Duſt naturally contained in the Atmoſphere; and at the ſame time loſes particles of Water, which are thus carried off by the Air; whence upon numerous repetitions of the Experiment, a large

propor-

proportion of the Earth obtained might proceed from the Duſt of the Atmoſphere *.

24. The Experiment by Congelation ſeems attended with fewer difficulties; and might perhaps be brought to determine the point with leſs exception; by uſing a Circle of Freezings and Thawings, alternately repeated, with care to ſeparate the Earth each time.

25. What we here term Elementary Water, is the pure aqueous part, which comes over in Diſtillation; and commonly called by the name of diſtilled Water. This diſtilled Water is found lighter and purer than the natural; provided it acquire no foulneſs, or heterogeneous parts in the Operation. And 'tis obſervable, that if the Operation were to be ſtopped in the middle, a groſſer Water remains behind, than what came over. Whence in all curious Chemical and Œconomical Uſes, the Water employed ſhould not boil too long; as particularly in the making of Tinctures, Tea, Coffee, *&c.*

## Experiment VI.

*The more commodious Methods of examining Water.*

*Common Water examined.*

26. By means of the Inſtrument called the Hydroſtatical Ballance, we took the ſpecific Gravity of the Water propoſed, and directly judged of its Goodneſs by its Lightneſs.

27. This Experiment is a good Subſtitute for ſeveral other ways of examining the purity and goodneſs of Waters; both common and mineral. For it appears by numerous Inſtances, that light Waters are, *cæteris paribus*, the beſt, pureſt and wholeſomeſt.



* See Mr. *Boyle*'s Philoſophical Works, and *Boerhaave*'s Chemiſtry.

28. But as the preſent Method requires the uſe of a curious Inſtrument; and a conſiderable degree of accuracy and attention, other more expeditious, tho' not more exact Trials have been invented; particularly by the uſe of *Water-poiſes*; which are Inſtruments of Ivory, Glaſs, *&c.* made hollow-bellied, ſo as to float, higher or lower, in Water, according as the ſpecific Gravity thereof is more or leſs: And theſe Inſtruments being graduated or divided by Lines on the Stem; they readily ſhew to the Eye, the difference betwixt the ſpecific Gravities of any two Waters propoſed; tho' not with the utmoſt exactneſs.

29. The foundation of both Experiments is this; that the Bodies diſſolv'd or lick'd up by Water, in its paſſing thro' the Caverns, or ſuperficial Parts of the Earth, are generally either ſaline or earthy: which being both more ponderous than pure Water; it follows, that the lighteſt Waters are leaſt impregnated with them; and therefore fitteſt for the finer uſes, where no ſuch groſs, ſaline or earthy Matters are required: as they particulary are not in the healthy human Body; where the ordinary office of common Water is to convey and diſtribute Nutriment to all the Parts, to dilute and waſh off the over-proportion of animal Salts, as it evidently does in the Sweat and Urine.

30. By means of the preſent Experiment, we find that the pureſt Rain-Water, is of nearly the ſame ſpecific Gravity with diſtilled Water: neither of them, when obtained pure, precipitating any groſs earthy Matter upon theaddition of Oil of Tartar *per deliquium*; as many Spring-Waters do.

31. Common-Waters are diſtinguiſhed into *Hard* and *Soft*, and accordingly are uſed for different Operations. Thus ſoft Water is found beſt for extracting certain Tinctures, freeing Metallic

*Calces* from their Salts, *&c.* And hard Water, for the tempering of Steel; the making of Artificial Wines, and Malt-Liquors intended for long keeping.

32. Hard Waters are such as contain a foreign, saline or terrestrial Matter; and accordingly become softer by long standing, or by a small addition of Salt of Tartar; both which tend to precipitate the terrestrial Substance out of them.

## Experiment VII.

### *The more commodious Method of examining Mineral Waters.*

33. (1.) To half a common Wine-Glass of *Pyrmont* Water, we added a Dram of the Syrup of Violets; whereby a greenish Colour was produced. (2.) To a like quantity of the same Water, we added a few Grains of scraped Galls; and first, a purple, then a blackish Colour presently ensued. (3.) We evaporated a quantity of the same Water; and a small proportion of an ochry Substance was left behind. (4.) We set a Glass of the same Water, cold, in the Receiver of the Air-Pump; and found, upon withdrawing the external Air, that the Water sparkled violently, and discharged a numerous quantity of small Bubbles, at its Surface; like what happens in the conflict of an acid and alkaline Liquor. *Mineral Waters examined.*

34. This Experiment holds in all the cases of Chalybeate Waters only, and not of *Mineral Waters* in general. By Mineral Waters in general, are meant all those wherein any Medicinal Virtues, besides those of common Water, is found. These Mineral Waters are of various kinds; we may consider them under the general Titles of *Chalybeate*, *Purgative*, and *Alterative*.

35. The more uſeful and commodious Additions for examining theſe three kinds of Mineral Waters, are, *Galls*, *Syrup of Violets*, and *Oil of Tartar per deliquium*.

36. *Galls* diſcover in them any ſmall proportion of Vitriol or diſſolved Iron; as having the property of immediately ſtriking a purple, or black Colour in all Waters, where any ſuch ſubſtance is lodged.

37. *Syrup of Violets* in the ſame manner diſcovers any ſmall predominancy of an Acid or Alkali therein; by changing the Water red, if an Acid; and green, if Alkali preſides.

38. *Oil of Tartar* diſcovers any ſmall proportion of earthy Matter, leſs capable of diſſolving in Water than that Salt; by precipitating ſuch earthy Matter, in form of a white Cloud, to the bottom of the containing Glaſs, where it collects, and appears like a ſubtile white Powder.

39. Theſe particulars may be ſhewn, and proved ſatisfactorily, by adding to pure Water a little of a known Acid, Alkali, diſſolved Iron and ſubtile Earth, or fine light Sediment of an earthy Water; applying the Syrup of Violets, Galls, and Oil of Tartar reſpectively.

40. Suppoſe, therefore, any unexperienced Water to be examined; firſt, drop into it a little Syrup of Violets; and if this does not alter its colour, but continues its full natural blueneſs; the Water is neither Acid nor Alkaline. If Galls do not turn the Water black, it is not Irony, or Vitriolic; and if Oil of Tartar does not precipitate a white Powder, the Water holds no conſiderable proportion of earthy Matter.

41. The preſent Set of Experiments is capable of great enlargement; by means of many other additions, capable of cauſing a change of Colour, or a precipitation in Waters; according as they

hey are impregnated with matters of certain kinds. Thus a Solution of Silver, by cauſing a thickneſs or light precipitation, diſcovers a minute proportion of Sea-Salt contain'd in Waters. And there s ſcarce a Salt on Earth, or a Mineral, hitherto known, but the induſtry of the Chemiſts has found ways of diſcovering, if it be contained in any common or Mineral Water; eſpecially, if to this we add the uſe of Evaporation, or way of bringing the ſolid Contents of ſuch Waters to a dry Form. So that if this whole affair were to be properly conducted; we apprehend it might in a ſhort time terminate in a certain diſcovery of the Contents of all the Mineral Waters of the Kingdom; to the great advantage of ordinary Life, and a conſiderable Improvement in the Art of Medicine; and many other Mechanical Arts and Trades, depending upon the proper Choice and Uſe of Waters.

## Experiment VIII.

*That Mineral Waters are imitable by Art.*

42. We took a Quart of the lighteſt and pureſt Water we cou'd procure, and added to it about thirty Drops of a ſtrong Solution of Iron made with Spirit of Salt; a Dram or more of *Oleum Tartari per deliquium*; and twenty, thirty, or forty Drops of Spirit of Vitriol; but ſo as that the Alkali of the Oil of Tartar might prevail: we ſhook now all briſkly together; and poured out a Glaſs for taſting; upon which, it was found very remarkably to reſemble *Pyrmont-Water*. Pyrmont-*Water imitated.*

43. This Experiment, tho' but particular, may afford us a general Rule, for imitating any Mineral Water propoſed. The Rule is, by a proper Analyſis to find the Contents of ſuch a Water,

Water, (by Evaporation, the addition of tinging Ingredients, *&c.* as above-mentioned *) and their proportions; then, by means of Synthetical Chemiſtry †, to compoſe a ſimilar Mixture. Thus, for example, we learn, by a proper Analyſis, that the Ingredients or different conſtituent Parts of *Pyrmont*-Water ‡, are a ſubtile aqueous Fluid, a volatile Iron, and a predominating Alkali; all joined together into one brisk, pungent, ſpirituous Water: And upon this Analyſis our preceding Imitation was founded; which if the proportions be juſtly hit, the Artificial *Pyrmont*-Water will greatly reſemble the Natural; and produce ſimilar effects in the Body; as has been found upon Experience ||.

44. The Imitation of this ſpirituous kind of Chalybeate Water is by much the moſt difficult; and may perhaps be rendred more perfect, if inſtead of uſing the Solution of Iron in Spirit of Salt; the pureſt common Water be boiled in a cloſe Veſſel, with a ſmall proportion of Okre, ſoft Iron Ore, or Pyrites; the reſt of the Proceſs being conducted as above ſet down.

*Purging-Waters imitated*

45. The Imitation of the common purgative Mineral Waters is facil; thus *Epſom*-Water is imitated by barely diſſolving three or four Drams of *Epſom* Salt, in a Quart of pure Water, made ſomewhat briſk or quick with a few Drops of Spirit of Vitriol, and Oil of Tartar *per deliquium*, ſo as to let the Alkali prevail. And the ſame is to be underſtood of any other Water, whoſe Contents are exactly known.

46.

* See *Exp.* VII. §. 35, 36, 37, *&c.*

† See hereafter the *Lecture* on Synthetical Chemiſtry.

‡ See above *Exp.* VII.

|| See New Experiments and Obſervations upon Mineral Waters.

46. And by a little farther Experience and Application we apprehend, that these Imitations might be brought to a great degree of Perfection; so as to render the trouble and charge of importing foreign Waters, or going to drink them abroad, in a manner unnecessary. *The Experiment extended.*

But the Imitation of the Alterative Waters, such as those of *Bath*, *Buckston*, *Holt*, *&c.* has hitherto scarce been attempted; nor can be rationally, for want of their respective just Analyses, upon which such Imitations should always be grounded.

## Axioms *and* Canons.

1. We have seen, (1.) that Water is naturally contained in some of the dryest and hardest Bodies; and in the dryest Air: (2.) that itself naturally contains Air, and and an earthy Substance; (3.) that it is the proper Menstruum of Salts; dissolving more of one, and less of another: (4.) that one good sign of its purity and wholesomeness is Levity: (5.) that the Ingredients of a Mineral Water may be discovered by Chemical Expedients: and (6.) that Mineral Waters are imitable by Art, from such Discovery *.

2. That Water is of infinite use in all the Works both of Nature and Art; as without it, there could be no Generation, Nutrition or Accretion performed in all the Animal, Vegetable, Mineral, Marine and Atmospherical Regions. The Blood could not flow in the Veins, the Sap in the Vessels of Vegetables, nor the Particles of Minerals concrete and grow together, without Water. 'Tis this that makes the largest part of our Blood, our Drink,

* See the *Lecture passim.*

Drink, and our Aliment. There could be no Corruption, Fermentation or Diſſolution carried on without it *. No Brewing, no Diſtilling, no Wines, no Vinegars, no Spirits, made without it †.

3. That we meet with Water under an infinite variety of Forms; and in an infinite variety of Bodies; as that of Air, Vapour, Clouds, Snow, Hail, Ice, Sap, Wines, Blood, Fleſh, Bone, Horn, Stone, *&c.* through all which it ſeems to paſs unaltered, as an Agent or Inſtrument, that ſuffers no alteration by re-action; but remains capable of reſuming the form of Water again, upon occaſion ‖. In which reſpect it greatly reſembles that other *Proteus*, *Quickſilver*, which we meet with in the form of Fumes, Clouds, Sublimate, Precipitate, *&c.* from which it may be reduced to running Mercury again **.

4. That Water, in its own common State, appears to be a combination of all the Elements together; as containing a quantity of Fire, which keeps it fluid; a quantity of Air, and a quantity of Earth ††. Whence it can be no wonder, that Water alone, as it appears to the Senſes, ſhould ſuffice for Vegetation in ſome caſes, where little Earth is wanted; or for ſupporting Animal and Mineral Life, where no great degree of Nutriment is required. And hence it proves a *Gluten* or Cement to ſome Bodies, and a Solvent to others. Thus it conſolidates Brick, Plaiſter of *Paris*, Stone, Bone, *&c.* but diſſolves Salts, and ſubtile Earths approaching to Salts, and becomes the Inſtrumental Cauſe of their Action ‖‖.

5.

* See *Lect.* I.

† See the whole Work *paſſim*.

‖ See *Exp.* I. *&c.* See alſo *Lect.* III.

** See Mr. *Boyle* paſſim.

†† See *Lect.* I. II. III. IV.

‖‖ See *Lect.* I. the preceding *Lecture* paſſim; and again, the *Lecture* upon Fermentation, *&c.*

5. That Water conveys Nouriſhment, or a more fixed and ſolid Matter, to the parts of Vegetables; where having depoſited it, the finer Fluid perſpires into the Atmoſphere *: which gives us the Phyſical Cauſe of the dampneſs and unwholeſomeneſs of woody Countries; as they remarkably find in *America*. For all large Vegetables act after the manner of Forcing-Pumps; and continually draw in large quantities of Water at their Roots, and diſcharge it at their Leaves. Which intimates a method of collecting Water in dry Countries; and again, of making Salt-Water freſh.

6. That the Water in paſſing thro' Plants, after having depoſited its more terreſtrial part, does not always go off pure, but impregnated with the finer Effluvia, or more ſubtile Particles of the Vegetable; thus making an Atmoſphere round every Plant, according to its Nature, odoriferous or otherwiſe. Which ſupplies us with a Rule for procuring the odoriferous Waters of Vegetables by Diſtillation †.

7. That the Particles not fine enough to go off thus along with the Water, are left behind upon the Surface of the Leaves, and Flowers of Plants; being now thickned or ſtrained from their moiſter parts, and remaining in the form of Honey, Manna, Gums, Balſams, *&c.* according to the Nature of the Vegetable ‡. And hence appears the Phyſical Cauſe of Plants proving more odoriferous and ſweet, when the Weather is both warm and moiſt; as immediately after a Summer's Shower.

8. That the Chemical Operator ſhould form to himſelf an *Hygrometer* ||, for the Service of his Labo-

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* See *Exp.* III. *&c.*

† See *Exp.* III. §. 12, *&c.*

‡ See *Exp.* III.

|| As of Sponge, Salt of Tartar, Oil of Vitriol, Oat-beards, *&c.* which attract the Moiſture of the Air.

Laboratory; to determine the proportion of Water at all times contained in the Air; which continually mixes with his Preparations, differently augments their weight, and promotes or hinders many of his Operations *, as we find particularly in making the *Oleum Sulphuris per Campanam*, and *Oleum Tartar. per deliquium*, both which ſucceed beſt in a moiſt Air *.

9. That pure Water makes the largeſt part of Mineral Waters, where it is impregnated as a Menſtruum with ſeveral Ingredients, that it diſſolves or drinks up in its paſſage thro' the Earth †.

10. *Laſtly*, The preceding Enquiry affords conſiderable light for diſcovering practicable ways of making Sea-Water freſh and potable ‖; and of preparing Waters by Art, ſo as to render them fitter for the common œconomical Uſes, and the Service of many particular Arts; as Medicine, Pharmacy, Chemiſtry, Brewing, Diſtilling, *&c* **.

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* See *Exp.* II. See alſo *Lect.* III. *paſſim.*

† See *Exp.* VII. VIII.

‖ See §. 7, 12, 14. & *Ax.* 5, *&c.*

** See §. 40, *&c.*

# LECTURE VI.

CONTAINING,

## *An Enquiry into the Nature and Uſe of Menſtruums, or Solvents.*

1. WE have now gone thro' with the common Elements, Fire, Air, Earth, and Water: we next proceed to *Menſtruums*; which make a large Branch of Natural Philoſophy, and a more peculiar and immediate part of Chemiſtry. *Introduction.*

2. By *Menſtruums* we underſtand all thoſe Bodies, which, in a fluid or ſubtilized State, are capable of interpoſing their ſmall parts, betwixt the ſmall parts of other Bodies; ſo as to divide them ſubtily, and form a new uniform Compound of the two. *Menſtruums what.*

3. Hence, ſolid Bodies, as well as Fluids, are capable of becoming Menſtruums; when their parts are ſubtily divided, ſo as to receive others uniformly between them: whether this ſubtile diviſion and joint interpoſition of Parts be effected by Fuſion, Triture, or the like. *Solid and Fluid.*

4. Thus when two Metals, being fuſed together, mutually interpoſe their ſubtile parts between each other, and unite into one uniform Maſs; they become Menſtruums to each other. And ſo when common Sulphur and common Mercury are barely rubbed together, till the Maſs becomes every way uniform, and ſimilar; the Sulphur proves a Menſtruum to the Mercury, and the Mercury a Menſtruum to the Sulphur; *The Definition illuſtrated.*

and

and form that black uniform Powder called *Æthiops Mineralis*.

5. Whence it appears, that the term Menſtruum is equally applicable to both the Bodies concerned; the one being as much a Menſtruum as the other. So when Water diſſolves Sugar, it may as juſtly be ſaid, that the Sugar diſſolves the Water; tho' Cuſtom, and the common Forms of Speech, which have little regard to juſt and philoſophical Notions, do not authorize the Expreſſion.

*The Menſtruums of Nature.*

6. And hence it may appear, that the common Elements we have conſider'd in the foregoing *Lectures*, are in a proper ſenſe the *Menſtruums of Nature*; which ſhe employs for producing her ordinary effects. For Fire mixes uniformly among Bodies, and divides their parts; ſo does Air, Water and Elementary Earth, as we have all along ſhewn. We ſuppoſe it will not, therefore, appear foreign, but directly conducive to our purpoſe, to have beſtow'd a *Lecture* upon each of theſe Elements, by way of Foundation to our Courſe; as theſe are not only the principal Agents of Nature, but are alſo concerned in every Chemical Operation.

*The Purport of the Experiments.*

7. The preſent Buſineſs will be to ſhew, (1.) the different diſſolving Powers of Water, in different Bodies. (2.) The ſame of Alcohol. (3.) The ſame of Oil. (4.) The ſame of unlikely Subſtances. (5.) The ſame of Quickſilver. (6) The ſame of the common Menſtruums, *Aqua Fortis*, and *Aqua Regia*. And, (7.) the ſame of the Digeſtor: thus proceeding gradually from the weakeſt up to the ſtrongeſt diſſolving Powers, hitherto known in Chemiſtry.

EXPERI-

## Experiment I.

*That Water, as a* Menſtruum, *diſſolves more of one Body, and leſs of another.*

8. We took three ſimilar and equal Glaſſes, each containing two Ounces of the ſame kind of Water, cold; and put into the firſt a certain weighed quantity of *Epſom* Salt, *viz.* two Ounces, the greateſt part whereof was ſoon diſſolved. We put into the ſecond a certain weighed quantity of dry and pulverized common Salt, *viz.* five Drachms; which likewiſe ſoon diſſolved, almoſt entirely. And into the third, we put a certain weighed quantity, *viz.* eight Grains of finely pulverized *Cream of Tartar*; ſcarce any part whereof appeared to diſſolve in the cold. We ſet all the Glaſſes in *Balneo Mariæ*, 'till the Water of the *Balneum* boiled, and then obſerved that more of each Salt was taken up reſpectively. *The different Power of Water as a* Menſtruum.

9. It might be proper, for the further Improvement of Chemiſtry and Natural Philoſophy, to form a Table of the Time and Quantity wherein all the known Salts are diſſolvable in Water. *Epſom* Salt, we ſee, preſently diſſolves in about an equal Quantity of Water; common Salt diſſolves in about four times; Nitre in about five or ſix times; and Salt of Tartar in about twice its own quantity of Water: but *Cream of Tartar* requires twenty times its own quantity of boiling Water to diſſolve it. *The Experiment extended.*

10. Such a Table, regularly formed, might eaſe the trouble of refining Salts, by ſhewing at once, without future trial or loſs of time, how much Water each Salt required to diſſolve it, for Clarification, Filtration, or Cryſtallization.

11. It would likewiſe ſupply us with a ready and commodious way of ſeparating any Mixture

of Salts, by ſhewing which would ſhoot out of the Mixture firſt upon Cryſtallization. For the Rule is, that *the Salt which requires the largeſt Proportion of Water to diſſolve it, will ſhoot the firſt.* And thus Nitre, requiring a larger proportion of Water to diſſolve it than common Salt does; Nitre, by Cryſtallization, is totally ſeparated from that Salt, in the ordinary Refinement of Nitre. And unleſs this were to happen, the *Aqua-Fortis* prepared from Nitre, would prove a kind of *Aqua-Regia*; and inſtead of diſſolving Silver, diſſolve Gold: For *Aqua-Regia* is made from a Mixture of Nitre and Sea-Salt, or Sal-ammoniac, which contains the Spirit of Sea-Salt *.

12. The ſame Table might alſo direct us to a ready and commodious Method of ſeparating two Salts, without waiting for Cryſtallization. Thus ſuppoſe *Tartar of Vitriol* were mixed with *Epſom* Salt; if Water be poured upon the Mixture, it will preſently drink in the *Epſom* Salt, and leave the *Tartar of Vitriol* untouched, ſo as to be decanted clear from it; becauſe *Epſom* Salt eaſily and plentifully diſſolves in cold Water; whereas *Tartar of Vitriol* diſſolves ſlowly and ſparingly in the ſame. And the ſame is to be underſtood of other Mixtures of Salts.

*Accounted for.* 13. If the phyſical Reaſon be demanded, why one Salt more readily diſſolves in Water than another, we recommend it to farther Examination whether all Salts do not diſſolve in Water with greater or leſs Facility, and in greater or leſs Proportion, according as they contain more or leſs, of a groſs, unctuous Subſtance, unſuitable to the Nature, or Fineneſs and Lubricity of Parts required in Water. The comparing of *Epſom*

* See hereafter *Exp.* VI.

*Epſom* Salt, Salt of Tartar, common Salt, *&c.* with Nitre, Alum, crude Tartar, *&c.* ſeem to make this more than a Conjecture.

14. Vitriols, being a Species of Salts, hence alſo become ſoluble in Water. But pure Water has not the power of diſſolving Metals, unleſs they are firſt reduced to a Saline or Vitriolic Form: Nor does Water act as a *Menſtruum* upon Oils, Roſins, Amber, Sulphur, *&c.* Whence its power, as a direct Solvent, is limited*: But for Salts, it ſeems the appropriated *Menſtruum*; and, with the aſſiſtance of other things, it may diſſolve a great number of other Bodies: Thus by the Interpoſition of Wax, it will diſſolve Oil by ſimple Triture, by means of the Yolk of an Egg it will diſſolve Turpentine, and by means of acid Spirits it will diſſolve Chalk, Earths, and Metals.

15. In our preſent Experiment we find the diſſolving Power of Water increaſe with Heat, and this holds 'till the Water boils; after which, as the Heat remains the ſame, ſo does the diſſolving Power; and as this Heat decreaſes, ſo does that Power; and lets part of the Salt fall down again. Whence it ſhould ſeem as if Heat was the original Cauſe of the diſſolving Powers.

16. But on the other hand, there are Experiments, wherein the Power of Water, as a *Menſtruum*, decreaſes, as the degree of Heat increaſes, *viz.* in boiling the White of an Egg; where the Water, as it grows hot, coagulates the Subject; which it would diſſolve when cold. We alſo obſerve the ſame of Blood; a firm Mixture of Flower and Water, *&c.* The Inſtances of this kind ſhould therefore be collected, and go along with the former, to prevent the Mind from running



* See *Lect.* V. §. 17, 18, &c.

ning into Error, and prevent our concluding haſtily from too few Experiments; which has greatly prejudiced Chemiſtry and Natural Philoſophy.

## EXPERIMENT II.

### *The diſſolving Power of* Alcohol.

*Camphire diſſolved in Spirit of Wine.*

17. We took an Ounce of *Alcohol*, and by degrees added to it an Ounce of ſolid Camphire; all which it nearly diſſolved, in a very ſhort time, without any Ebullition, or apparent Alteration of Fluidity, or Tranſparency. We afterwards poured in a large proportion of fair Water, which weakening the Solution, and uniting with the *Alcohol*, cauſed it to let go the Camphire; that now all roſe white, ſolid and perfect, to the top of the Mixture.

Alcohol *what.*

18. *Alcohol*, or highly rectified Spirit of Wine, is a Liquor obtain'd from vegetable Subjects, by Fermentation, Diſtillation, and Rectification *. It appears related to Oil, becauſe totally inflammable; and when carefully examined, to be the eſſential Oil of the Vegetable, intimately broke and ground in, among the Particles of Water; ſo as to form one uniform Liquor, not eaſily ſeparable again into different parts †.

19. We learn, by the preſent Experiment, that it has the power of diſſolving about its own weight of Camphire; which when duly examined, appears to be a particular kind of volatile, or eſſential Oil, coagulated into a white and ſolid Subſtance †. And as ſuch an Oil, it is here plentifully diſſolved in *Alcohol*.

*Its Uſes.*

20. This *Alcohol* is a capital *Menſtruum* in Chemiſtry, and fitted to diſſolve Roſins, as well as

* See the *Lecture* upon *Diſtillation* hereafter.

† See hereafter *Lect.* XVI. *Exp.* III.

as Oils. Tho' it does not thus mix inextricably with either, but leaves them ſeparable again by the bare addition of Water, which it diſſolves more readily than either Oil or Roſin; and therefore lets them go to join with this, according to the Law of Precipitation. For *whenever one Body has diſſolved another; and a third be added to the Solution; which third has a greater relation to either of the former, than they have to each other; their Union is ſeparated, and the third Body diſſolved inſtead of the firſt or ſecond; one of which is now at liberty to riſe, or fall to the bottom, according to its ſpecific Gravity:* as we ſaw remarkably in the preſent Experiment, where the Camphire, diſſolved in the Spirit of Wine, was ſoon made to float upon the Surface, by the addition of Water, which has a greater Appetite of Union, or Relation, to Spirit of Wine, than that Spirit has to Camphire. And the phyſical Reaſon hereof may appear from what was juſt now ſaid of the Compoſition of this Spirit; or its being an intimate Mixture of Water and volatile Oil *.

21. Hence *Alcohol* is an intermediate Subſtance, betwixt Oil and Water, and related to both, tho' participating more of Water than of Oil: And according to theſe Relations, its Action as a *Menſtruum* may, we conceive, be properly explained.

22. It is by means of this *Menſtruum*, that the Tinctures of *Myrrh*, *Gum Lac*, *Guaiacum*, moſt of the Varniſhes, and many medicinal Tinctures, Elixirs, and Solutions are prepared: Tho' for theſe purpoſes it uſually requires to be acuated with Salt of Tartar. But our preſent buſineſs is rather to conſider the power of ſimple *Menſtruums*, than of ſuch as are mixed; which were an infinite Field, and would lead us too far for



* See §. 18.

the preſent. Tho' the Diſcovery of powerful, yet innocent *Menſtruums*, by means of Compoſition, ſhould be earneſtly recommended to the Diligence of every Chemiſt, as that whereon the Improvement of numerous Arts depends.

## EXPERIMENT III.

### *That Oil will intimately diſſolve Lead.*

*Oil diſſolves Lead.*

23. We put two Ounces of crude Lead into an Iron Ladle, and added thereto twelve Ounces of Oil-Olive, then ſet them over a clear Fire; the Lead evidently melted before the Oil began to boil, and at length the Lead diſappeared, or united and became one with the Oil. By ſtopping the Operation at any time, we could eaſily learn how much of the Lead was diſſolved in the Oil, both by the increaſed Conſiſtence of the Oil, and the Diminution of the Lead.

*The Experiment extended.*

24. The ſame Experiment may hold alſo of Tin; and in a Mixture of Tin and Lead. How far it is applicable to the other Metals, has not been hitherto ſatisfactorily tried. Some have ſuppoſed that Oil will diſſolve Copper and Iron: But it ſhould be carefully examined whether the effect be not here owing to an Acid, concealed in the Oil; for it is the known Property of Acids to diſſolve theſe Metals. This has been obſerved, that if Oil be well boiled, to get out its aqueous Parts, it is the better fitted to preſerve Utenſils of Iron, Braſs, or Copper, from Ruſt. Whence Marrow is reckoned better for this purpoſe, than other Fats or Oils, more ſubject to harbour aqueous Moiſture. And if a little Ceruſe, or Black Lead, be added in the boiling, the Oil becomes ſtill more proper for this purpoſe. But it is the Property of Ceruſe, and black Lead, to drink up Acids; and therefore it may be hence concluded,

concluded, that ſome acid parts, naturally contained in Oils, are the cauſe of their ruſting or diſſolving the Iron, Braſs, or Copper, whereon ſuch Oils are laid.

25. The Preparation, or Subſtance, obtained in the preſent Experiment, being taken from the Fire at different times of the Operation, makes either a Balſam, a Cement, or a Plaiſter; fit for various Uſes. As a Balſam, and a Plaiſter, it is ſerviceable in Chirurgery. As a Cement, it is excellent in Water-Pipes; and being laid upon hot Brick-work, or the like, fits it for holding Water. It alſo ſerves to hold crack'd Glaſſes together; ſo that they ſhall be as firm in the crack, as in the ſound parts. *Its Uſes.*

26. But a more phyſical Uſe of the Experiment is to ſhew the great Affinity, which the ſoft and fluid Body of Oils, as a *Menſtruum*, has with the ſolid Bodies of Metals; and how they may mutually, not only diſſolve, but diſguiſe and conceal each other; ſo that Metals ſhall be contained in Bodies, where the Eye would never ſuſpect them.

27. The preſent Experiment alſo affords ſome Light in the Doctrine of Solders; or, the Mixtures of metalline Matters, that will run with a leſs Degree of Heat than the Metal propoſed to be ſolder'd, and tenaciouſly lay hold thereof. For Oil, or Greaſe, is an uſeful thing to facilitate the running of theſe Solders; as we ſee in the ſoldering of Lead and Tin, where the Plumber uſes his Tallow; as the Tinman does his Roſin: by which means, the Solder and the Metal are the better ſoften'd, and in ſome meaſure diſſolved in together.

28. We deſire that this great Affinity betwixt Oil and Metals may be remember'd; as being *The Relation betwixt Oils and Metals.*

being an extenſive Obſervation in the Buſineſs of Metals, and more particularly in the ſublimer Metallurgy; where certain Expreſſions uſed of the *Sulphur of Metals*, may be underſtood to advantage, by taking them to mean an actual inflammable Subſtance, or Oil.

## EXPERIMENT IV.

*That innocent and unlikely Subjects may afford powerful* Menſtruums, *ſhewn in Bread.*

*Bread diſtilled.*

29. We took two Pounds of common brown Bread, cut into ſmall Pieces, and put it into a Glaſs Retort. We placed the Retort in a Sand-Heat, and luting on a Receiver, diſtilled with a moderate Fire, ſo long as any aqueous Liquor came over; and at length ſuffering all to cool, we took off the Receiver, and by the Filtre ſeparated the Liquor obtained, to clear it of its Oil. This Liquor was afterwards rectified from its Phlegm in *Balneo Mariæ*, and afterwards in a Sand-Heat diſtilled over again, ſo as to obtain a moderately ſtrong, acid, and limpid Liquor, under the name of the rectified Spirit of Bread.

*Uſes of the Experiment.*

30. In this manner, we obtain from common Bread, a large proportion of an aqueous Liquor, mixed with acid parts, ſo as to be capable of extracting the red Colour out of Coral, or even Garnets. But to procure this Liquor in its greateſt Strength and Perfection, we ſhould make uſe of Rye-Bread, or ſome of the coarſer ſorts.

31. The Experiment being duly proſecuted, affords us the Analyſis of Bread; a Subſtance capable of recruiting and forming all the ſolid Parts of our Bodies. And no wonder, ſince it contains nearly the ſame Principles as animal Matters. For Blood, Fleſh, or Bone, upon their Analyſis, reſolve into Water, Oil, volatile Salt,

and

and Earth; the whole, by Decoction, making a kind of mucilaginous, or gelatinous Subſtance with Water. Accordingly, Bread boils with Water into a gelatinous or mucilaginous Subſtance; and when diſtilled, reſolves into Water, an acid Spirit, Oil, and Earth. The principal Difference betwixt them is, that Bread affords a volatile Acid by Diſtillation; as Fleſh, or Blood, affords a volatile *Alkali*. Whence it ſhould ſeem, that there is in the Body a certain power of changing the matter of an *Acid* into that of an *Alkali* *.

*Extended.*

32. To gain a clearer Information from the preſent Experiment, we could wiſh it repeated with ſuch Bread, as contains no Sea-Salt; which is a common Ingredient in the uſual kinds of Bread. For Sea-Salt affords a conſiderable proportion of acid Spirit upon Diſtillation, and this Spirit may have a great ſhare in diſſolving the Bodies, ſuppoſed to be diſſolved by the Spirit of the Bread. But however that matter may prove, the Experiment ſhews a powerful *Menſtruum* is obtainable from an innocent and unlikely Subject. And the ſame has been found to hold of many other Preparations; as Wine-Vinegar, tartarized Tartar, *&c.* Whence the like Experiments ſhould be tried upon other common Subjects; ſuch as the Yolk and White of Eggs; Rennet, Curd, Whey, Milk, Butter-Milk, Cheeſe, Urine, *&c.* in order to diſcover whether ſerviceable *Menſtruums* might not be thus procured.

## Experiment V.

### *That Quickſilver diſſolves Metals.*

*Amalgamation of Lead.*

33. We melted two Ounces of clean Lead in an Iron Ladle, and heated the ſame quantity of Quick-

* See more to this purpoſe in *Lect.* VII.

Quickſilver in another Ladle, 'till the Quickſilver juſt begun to fume; then poured the Quickſilver to the Lead, and ſtirred them both together with an Iron Rod; then letting them cool, they made a white, hardiſh, homogeneous Maſs: a part of which being ground with more freſh Quickſilver, readily and intimately mixed therewith.

*The Experiment extended, with its Uſes.*

34. This Experiment ſucceeds with all the Metals, except Iron; which therefore appears of a leſs mercurial nature than the reſt. The Operation itſelf is called *Amalgamation*; that is, the intimate mixing of a Metal with Quickſilver. It is the Foundation of Gilding and Silvering. For an Amalgam of Gold being rubbed upon a well-poliſhed Plate of pure Silver; and the Plate afterwards expoſed to ſuch a Degree of Heat, as will evaporate the Quickſilver of the *Amalgam*; the Plate is thus left gilt. The Caſe is the ſame when Copper is to be ſilver'd. And thus Gold, or Silver, is uniformly diffuſed through the Body of the Quickſilver; whence a ſingle Grain of Gold, Silver, Lead, or Copper, may be divided to an almoſt inconceivable Degree; or ſpread uniformly through a Maſs of a thouſand pound weight of Quickſilver, every the ſmalleſt Particle of which Whole, ſhall contain a proportionable Quantity of Gold to the Whole. And hence it appears, that Quickſilver is a true *Menſtruum* to all the Metals, except Iron; diſſolving them as perfectly as Water diſſolves Salt.

35. The preſent Experiment alſo ſhews us, how Quickſilver may be adulterated with a Proportion of Lead; but the Fraud is eaſily diſcovered, by putting a little quantity of ſuch debaſed Quickſilver into an Iron Ladle, and exhaling away all the Mercury; which will thus leave the Lead behind.

36.

36. We may likewiſe hence underſtand the raudulent Tricks of ſome pretended Alchemiſts; who feigning an occaſion for the Uſe of Mer-ury in their Proceſſes, have beforehand diſ-olved, or procured to be ſecretly diſſolved, a ertain proportion of Gold or Silver; which not lying off along with the Quickſilver in the Fire, hus makes the credulous By-ſtanders believe, hat the baſer Metals employed, are enriched with the nobler in the Operation. The Inſtan-es of ſuch Frauds are many, and have brought great Stain upon the Art of *Alchemy*. But hey are eaſily detected, by expoſing a part of he Operator's Mercury to the Fire; where all he Quickſilver going off in fume, will leave he Silver and Gold behind.

## Experiment VI.

*hat* Aqua-Fortis, *or Spirit of Nitre, is the* Men-ſtruum *for Silver*; *and* Aqua-Regia *the* Men-ſtruum *for Gold.*

37. We took two Drachms of the fineſt Silver educed to Filings, and poured upon it twice its veight of proof *Aqua-Fortis*; then ſet the con-aining Glaſs in a ſoft Heat, under a Chimney, till the Solution was perfectly made. *Gold and Silver diſ-ſolved.*

38. We took ten Grains of Leaf-Gold, and oured upon it two Drachms of *Aqua-Regia*; hen ſet the Glaſs in a Sand-Heat to warm tho-oughly. After the Gold was diſſolved, we ad-led a Grain or two more, 'till the *Menſtruum* vas fully ſaturated: then decanted the clear ellow Solution. We afterwards put a few Grains f Silver into *Aqua-Regia*, and a few Grains of Gold into *Aqua-Fortis*; and kept the containing Glaſſes warm, in the ſame manner as before, but ound no Solution enſue in either caſe.

39.

39. Thus we ſee that Gold and Silver are perfectly diſſolved in their reſpective *Menſtruums*; neither of which will touch the other Metal. For if any Gold be contained in the Silver, it will fall to the bottom of the Solution in the form of a black Powder; and if any Silver be contained in the Gold, it does the ſame.

Proof Aqua-Fortis *what.*

40. The *Aqua-Fortis*, for the Solution of Silver, ſhould be made *Proof*; that is, it ſhould be capable of diſſolving half a Grain, or a Grain of Silver immediately, without growing in the leaſt turbid; as it wou'd do, if it contained any Sea-Salt; in which caſe it is a kind of *Aqua-Regia*.

*How made.*

41. *Aqua-Fortis* is made by diſtilling putrified Nitre with calcined Vitriol, or rectified Oil of Vitriol, in a ſtrong Heat; whereby an extremely corroſive acid Liquor is driven over in blood-red Fumes.

Aqua-Regia *what.*

42. *Aqua-Regia* is made by diſſolving a fourth part of Sea Salt in the *Aqua-Fortis* above mention'd.

*Uſes of the Solution of Silver.*

43. If the Silver employed in the Solution were abſolutely pure, the Liquor will be pellucid but if any Allay, or Copper, remain mixed with it, the Solution will have a bluiſh or greeniſh caſt. If a Solution of perfectly pure Silver be diluted with fair Water, it will ſtill remain pellucid, without letting any thing precipitate. But if any ſaline matter be contained in the Water the whole will now turn thick or milky. The Solution of pure Silver, properly weaken'd with Water occaſionally, may be commodiouſly uſed for ſtaining the Skin, or other animal Subſtances black. And if white, grey, or red Hair be moiſtened with it, the Hair will ſoon become of a beautiful brown, or jet-black Colour. For which purpoſe it may be uſed with Safety: Care being taken not to touch the Skin therewith; for thu

thus a Blackneſs would be occaſioned, that requires many Days before it goes off again; but it diſappears at length, by the Scarf-Skin ſcaling off, without cauſing pain, or leaving any Sore behind.

44. The Solution of pure Silver has an intolerably bitter Taſte; tho' by the Eye it be not diſtinguiſhable from fair Water. Whence we have an eminent Inſtance how Metals may lie concealed from the ſight, or remain lodged in unſuſpected Liquors, and thence be introduced inviſibly into other Subſtances. Whence the greater Caution ſhould be uſed with all Pretenders to the Melioration and Tranſmutation of Metals.

45. This Solution of Silver is the Foundation of ſeveral medicinal and chemical Preparations; as the *Vitriol of Silver*, the *Lunar Cauſtic*, the *Silver Pill*, &c.

*The Silver how recoverable.*

46. The Silver is recoverable from this Solution, barely by ſuſpending a Copper-Plate therein: For Copper being more eaſily diſſolved by *Aqua-Fortis* than Silver; the Silver is therefore precipitated to the bottom, in the form of a Powder; and being waſhed and melted, comes into a metalline Lump again. And this alſo is to be underſtood of the Solution of Gold.

*Uſes of the Solution of Gold.*

47. But, on the contrary, the Solution of Gold is yellow, or gold-colour'd, and tinges the Skin purple, as the Solution of Silver ſtains it black. It may be further added, that if the Solution of Gold be precipitated with Salt of Tartar, and the Powder be carefully dried, it makes the *Aurum fulminans*, ſo called from the violent Exploſion it goes off with, when heated beyond a certain Degree *.

EXPERI-

* See hereafter the *Lecture* upon *Pyrotechny*.

## EXPERIMENT VII.

*The diſſolving Power of the* Digeſtor ; *an Inſtrument contrived at once to direct the Action of Water, Air, and Heat, in a high Degree, upon a Subject.*

*The Structure and Uſe of the Digeſtor.*

48. The *Digeſtor* is a ſtrong Veſſel, made of Copper, or Iron, and fitted with a cloſe Cover and Skrews, ſo as to remain perfectly tight, in a conſiderable Degree of Heat ; whilſt Water, common Air, and the Subject of the Operation are contained within.

*Ox-Bone ſoften'd.*

49. We took a pound of freſh Ox-Bone in a ſingle piece ; and two Quarts of common Water ; then a conſiderable Space being left for the Atmoſpherical Air, we ſkrewed them all up together in the *Digeſtor* ; and applied a moderate Degree of Heat to the bottom thereof, for about a quarter of an Hour, or 'till a Drop of cold Water, let fall upon the Cover, would evaporate in a very few Seconds of Time : then letting all cool, we opened the Veſſel, and found the Bone ſoft and tender, ſo as to be cut with a Knife ; with the Water, turned to a hard Jelly, about it ; and a large quantity of Fat in a ſolid Cake at the Surface.

*Rationale of the Experiment.*

50. The Effects of this Inſtrument will not appear ſurprizing, if the Forces, that act within it, be duly conſider'd. For, as we have formerly ſhewed the inſtrumental Efficacy of Fire, Air, and Water to be very great, even when ſeparate : no wonder they ſhou'd act extremely ſtrong upon a Body in conjunction *.

*Its Uſes.*

51. Hence the *Digeſtor* ſeems, of all the Inſtruments, or Veſſels, hitherto invented, the moſt pow-

* See the five preceding Lectures, *paſſim*.

powerful for increaſing the Action of *Menſtruums*. And if a ſuitable Method can be diſcover'd for ſtrengthening the Engine, ſo as to work ſafely with a very ſtrong Degree of Heat; we might reaſonably expect, that ſome very extraordinary Operations might be performed by its means; in the way of Extraction, Decoction, Tincture, Solution, and perhaps even Deſtruction, or Tranſmutation *.

52. But a Courſe of Experiments and Lectures upon this Engine alone, would ſcarce be ſufficient to ſhew and explain its numerous Uſes and Applications for improving the Doctrine of *Menſtruums*. And what Effects the common Solvents, as *Alcohol*, *Oils*, *Aqua-Fortis*, *Mercury*, and Metals themſelves, might have, when aſſiſted by this Engine, is not eaſy to foretel; and require much Induſtry and Application to diſcover.

## Axioms *and* Canons.

1. We learn, from the preceding Enquiry, that Water is a *Menſtruum*, which, of itſelf, diſſolves little more than Salts †; but, being aſſiſted by Acids, diſſolves Earths, and even Metals themſelves ‖. And hence a *general Rule of Practice* might be drawn, for making Water an almoſt univerſal *Menſtruum*. Thus, by the addition of a fixed Alkaline Salt, it diſſolves Oil into a Soap; by the addition of *Alcohol*, it extracts the reſinous Tinctures of Vegetables; and in this manner, it might be proper to run through the different Subjects of the vegetable, animal, and mineral

* See Dr. *Papin*'s Treatiſe of this Inſtrument. See alſo the Lord *Bacon*'s Philoſophical Works, *paſſim*.

† *Exp.* I. See alſo *Lect.* V.

‖ *Exp.* I. VI.

neral Kingdoms, and form Tables of the ſolutive Powers of Water, ſeparate, and in conjunction.

2. That ſuch Tables may be readily formed of the diſſolving Power of all the known *Menſtruums*; to ſhew by Inſpection, in what Time, in what Proportion, and with what Degree of Heat, all Solvents perform their Action: which being once reduced to a certainty, would greatly facilitate and improve the Practice of Chemiſtry*.

3. That the Power of *Alcohol*, as a *Menſtruum*, is chiefly limited to Roſins and Oils; but, by certain Additions, may be extended, as was ſaid of Water, ſo as to become an almoſt univerſal Solvent †. Thus, by the addition of Water, it becomes Brandy, or Spirit, which extracts many Tinctures that pure Water and pure *Alcohol* will not ſeparately extract. Whence we have a good Inſtruction for attempting a new Set of *Menſtruums* by Mixture, or the Compoſition of two or three ſimple Solvents. And if the requiſite Care and Skill were employed in this matter, many uſeful Diſcoveries might be juſtly expected from it. Indeed, the mixing of two *Menſtruums* may ſometimes deſtroy the Virtue of both; thus Spirit of Nitre and ſimple Water will each of them ſeparately diſſolve the human *Calculus*, but not touch it when they are mixed. But this Inſtance is only particular, and there are a large number producible on the contrary ſide: which may rationally recommend a farther Proſecution of this Enquiry.

4. That Metals are ſoluble in Oils, and acid Spirits, ſo as not to be eaſily diſcovered therein ‖. Whence a Rule may be drawn for a prudent Suſpenſion of the Judgment, and a rational Diſtruſt

* *Exp.* I. See alſo *Lect.* V.
† *Exp.* II.
‖ *Exp.* III. VI.

truſt of the Senſes in Chemical Operations: And again, a Caution derived againſt being impoſed upon by the vain Pretences of Alchemiſts *.

5. That the Power of a *Menſtruum* is not to be judged of by its Innocency, with regard to the animal Body. The acid Spirit of Bread is innocent and wholeſome; yet capable of diſſolving Coral and Gems †. Pure Oil-Olive will diſſolve Lead and Tin. The White of an Egg, boiled hard, and ſuffer'd to run *per deliquium*, diſſolves the tough Body of Myrrh. The Inſtances of this kind are extremely numerous. They well deſerve to be collected and tabled, that the Mind may be thereby cured of the Prejudice it readily has imbibed, as if only Corroſives were Solvents.

6. That the Action of *Menſtruums* depends upon a certain ſecret, and reciprocal Relation betwixt the Solvent and Solvend; ſcarce cognizable by the direct Senſes, nor hitherto well made out by Inſtances, and Induction. Alkali and Acid, Attraction and Repulſion, Sympathy and Antipathy, ſeem rather words coin'd to expreſs the Action, than to aſſign the phyſical Cauſes of it. And hence the Action of new *Menſtruums* cannot be determined, or rationally conjectured, beforehand: Becauſe this Action depends upon a Cauſe not hitherto known.

7. That *Menſtruums* have not their full Action, unleſs reduced to a fluid or ſubtile State ‖. Water in the firm and ſolid form of Ice does not act on Salts; but they ſoon begin to diſſolve each other upon Contact. Metals do not act on Metals, in the way of Solution, 'till they are fuſed: Nor does *Sulphur* diſſolve *Quickſilver*, 'till they are both reduced, either to a fluid or very



* See above, §. 26, 33—36.
† *Exp.* IV.
‖ See the Lecture, *paſſim*.

ſubtile State by Triture, or Melting. And this appears to be the Caſe in all Inſtances. Whence, to promote the Action of *Menſtruums*, we are directed to reduce both the Solvent and Solvend to minute parts, or the neareſt poſſible to a fluid State, whether by Heat, Triture, Fuſion, or otherwiſe. And hence appears the phyſical Cauſe of the ſingular Efficacy of Fire, Air, Water and Trituration in promoting the Action of *Menſtruums* *.

8. That Quickſilver is a true Solvent of Metals; ſo as to drink them in, as Water drinks in Salts †; by which means one Metal may be readily united with another, in any proportion, by ſimple Triture ‖. And by means of this Amalgamation, many Operations in the ſublimer Metallurgy are chiefly performed **.

9. That acid Spirits are not, equally, proper *Menſtruums* to all the Metals; thus Spirit of Nitre, tho' it diſſolves the reſt, will not diſſolve Gold ††. So neither is Quickſilver itſelf a proper *Menſtruum* to them all; for it does not diſſolve Iron ‖‖. And the true phyſical Reaſon hereof ſeems not hitherto ſatisfactorily diſcover'd; tho' numerous Conjectures have been made about it.

10. That all the Bodies in nature may become *Menſtruums* to one another, each of them being, by ſome means or other, capable of having their ſmall parts uniformly interpoſed betwixt the ſmall parts of any of the reſt. Thus even Metals may, by Art, be made to diſſolve in Water; as we evidently ſee from numerous Solutions of Metals in

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* See the five preceding Lectures, *paſſim*.

† *Exp.* I. and V. See alſo *Lect.* V.

‖ See above, §. 33, 34.

** See hereafter the Lectures on *Minerology* and *Metallurgy*.

†† See *Exp.* VI.

‖‖ *Exp.* V.

in acid Spirits: theſe Spirits being no more than Water charged with the finer or more volatile parts of Salts.

11. That the Cauſe, commonly aſſign'd, of Solution, *viz.* the admiſſion of the fine Particles of one Body into the Pores of another, whoſe Figure fits them for their reception, is not juſt or adequate, but hypothetical and ill-preſumed: Since we find that ſome Bodies will uniformly diſſolve their own quantity of others *; as Water does of *Epſom* Salt, *Alcohol* of eſſential Oils, *Mercury* of Metals, one Metal of another, *&c.* whereas the Sum of the Pores, or Vacuities, of every Body muſt be neceſſarily leſs than the Body itſelf; and conſequently thoſe Pores cannot receive a quantity of Matter equal to the Body wherein they reſide: for this were to make the contained Matter bigger than the Pores that contain it.

12. That the diſſolving Power of Water may be immenſely increaſed by means of the *Digeſtor*, an Inſtrument not hitherto introduced into Chemiſtry; tho' probably applicable to the great Improvement of that Art; as being a Contrivance, which at once determines the Action of a Solvent upon the Solvend, with all the advantages of Heat, Air, and Water, briskly agitated and confined, under a State of Compreſſure; ſo as to make them act like different Sets of Stampers upon the Matter to be changed. For this Engine at once employs all the four Agents required to make the greateſt part of *Menſtruums* act with advantage; *viz.* Fire, Air, Water and Triture. Whence there are ſome ſolid Grounds of Hope, that it may, under a proper Regulation, greatly contribute to the Improvement of Chemiſtry, natural Philoſophy, and Arts.



* *Exp.* I. II. V.

13. Upon the whole, it ſhould ſeem, that many deſirable Improvements are derivable to Arts from an Improvement in the Buſineſs of *Menſtruums* *. The Diſcovery of that common *Menſtruum*, *Aqua-Fortis*, introduced the Art of Aſſaying, and the Scarlet Dye. That of *Alcohol* introduced the Arts of Varniſhing, and Japanning. Numerous Pigments for Painters, Colours for Dyers, Tan-Liquors for Tanners, the Staining of Bone, Horn, Ivory, Marble, various kinds of Ink, Tinctures, and Solutions, in Medicine, Chemiſtry, and other Arts, have all reſulted from the Diſcovery of *Menſtruums*. Yet the Subject ſeems almoſt as new and rich, as ever; ſo that numerous other Diſcoveries, of the ſame kind, could not exhauſt it.

* See the whole Enquiry, *paſſim*.

# LECTURE VII.

CONTAINING,

*An Enquiry into the Nature, Office, and Effects of* Fermentation *and* Putrefaction, *in the Vegetable, Animal, and Mineral Kingdoms.*

1. THE Purport of this Lecture is to enquire into the Nature, Effects, and Uſes of Fermentation and Putrefaction, as they are the natural Means of converting one Body into another; in order to acquire a farther Knowledge into the *Chemiſtry of Nature*; and thence derive ſome ſerviceable Rules for the Improvement of *Philoſophical Chemiſtry*. *The Subject.*

2. But as the Subjects of Fermentation, and Putrefaction, ſeem to have been imperfectly treated by Authors, and to lie buried, as it were, in Obſcurity; we ſhall endeavour to let ſome Light in upon them, by particular Experiments, and their Explanations; ſo as to ſhew the Steps of *Nature*, and *Art*, in conducting and regulating theſe *capital Operations*, for altering and changing Vegetable, Animal, and Mineral Subjects in the three grand Regions of Nature, *viz.* the *Earth*, *Ocean*, and *Atmoſphere*.

3. To proceed in the clearer Method, we ſhall begin with *Fermentation* in Vegetable Subjects, and trace it thro' all its Stages; 'till at length terminates in *Putrefaction*: which reduces Vegetable Subjects to an animal Nature. Next, we ſhall conſider the ſimilar Proceſs in animal *The Order.*

Subjects; and *laſtly*, examine whether any thing of the ſame kind obtains among Minerals.

I.

We begin with vegetable Subjects.

EXPERIMENT I.

*The Nature and Uſes of vinous Fermentation: or the way of changing the natural Juices of Vegetables into Wines.*

*Wine made from Raiſins.*

4. We took a quarter of an hundred of whole, or unbruiſed, *Malaga* Raiſins, and put to them ſeven Gallons of cold Spring-Water, in a wooden Veſſel, or Caſk; which we ſet looſely cover'd in a warm place, that the Contents might ferment for ſome Weeks. The Water we found thus ſoaked thro' the Skins of the Raiſins, diſſolved their internal ſweet, or ſaccharine Subſtance; and became impregnated therewith, as a *Menſtruum*; that the Liquor manifeſted an internal Struggle, and Commotion of its Particles; throwing up numerous ſmall Bubbles to the Surface, with a conſiderable hiſſing Noiſe: and after the Fermentation was finiſhed, the Liquor became an actual new Wine; as appear'd by the Taſte, Smell, and Effects; having depoſited a large quantity of groſs, earthy Sediment, called Lees, at the bottom; different from the Huſks, or Skins and Stones of the Raiſins.

*The Experiment extended.*

5. This Experiment is univerſal; or ſhews the general manner of making Wines, and all other ſpirituous potable Liquors, or Drinks, by Fermentation. For, with a ſlight Change of Circumſtances, it is applicable to the brewing of Beer from Malt; Mead, or Metheglin, from Honey; Cyder, and Perry, from Apples and Pears

Pears reſpectively; artificial, or made Wines, as they are vulgarly called, from Cherries, Gooſeberries, Currants, Elder-Berries, Blackberries, Plumbs, Oranges, or other Fruit; again, from the Tappings of certain Trees, as the Birch, the Maple, the Sycamore, *&c.* and more eminently from the Juice of the Sugar-Cane, Treacle, or direct Sugar and Water. For any of theſe vegetable Juices, being duly fermented, afford as real and perfect Wine, according to their ſeveral Natures; as the richeſt Grapes of the beſt Wine-Countries.

6. To bring any of theſe Juices into a ſound Wine, the Rule is, either to evaporate them, if they are naturally too thin, 'till they become of equal richneſs with the Juice of the Grape in Wine-Countries, and good Wine-Years. This may commodiouſly be done, by means of the common Water-Poiſe*, which ſhews the Strength, or Richneſs of Solutions to the Eye. And in general, any vegetable Juice, or Solution, is accounted ſufficiently rich for making a ſtrong Wine, when it will ſupport a new-laid Egg on its Surface. *And applied; with its Uſes.*

7. The Wines made at preſent in *England*, lie under a diſrepute; the Reaſon whereof ſeems chiefly owing, *firſt*, to the inartificial manner wherein they are uſually prepared; and, *ſecondly*, to a certain Rumour ſpread about them, as if they were unwholeſome, crude, indigeſtible, too luſcious, too tart or griping, and apt to occaſion the Head-ach, *&c.*

8. Thoſe, who have never been in Wine-Countries, nor otherwiſe made themſelves acquainted with the Nature and common Preparation of



* See *Lect.* V. *Exp.* VI.

Wines, proceed, in their Judgment of them, according to Report, popular Notions, and the immediate Information of the Senſes. Thus, for inſtance, Red-Port Wines, to pleaſe the common Palate, muſt be bright, deep-colour'd, rough, rich, and racy, two or three Years old, *&c.* and when this, or any other Notion, comes once to be eſtabliſhed as the *Criterion* of Wine; the Cooper is thence directed how to hit the general Taſte, and make a ſaleable Commodity.

*Theory.* 9. Upon the ſame Foundation *Philoſophical Chemiſtry* inſtructs us to imitate the Wine-Cooper; and from almoſt any ſweet and tart vegetable Juice, to make ſaleable Wines; even Sacks, Mountains, Sherries, or Ports: all which, by the way, are uſually mixed Liquors; tho' the Baſis of them all is the Juice of the Grape.

10. This Juice of the Grape, being chemically examined and conſider'd, proves to be no more than a large Proportion of real *Sugar* diſſolved in Water, with the addition only of a certain Flavour in the Juice of the Grape; according to the nature of the Vine. Whence we lay it down as an *Axiom*, and the reſult of a careful Enquiry, that a *ſaccharine Subſtance is the Baſis of Wines.* For Sugar is not peculiar to the Sugar-Cane, but obtainable alſo from Grapes; and accordingly, we often find large Grains thereof in dried Raiſins; particularly thoſe of *Malaga*, that have laid for ſome time, and ſweat together; whereby they run into Candy, a ſaccharine Efflorescence, and actual Grains of Sugar. So again, 'tis cuſtomary in *France*, to evaporate the Juice of the Grape, 'till it becomes coagulable in the Cold, and in this ſtate to uſe it as a moiſt Sugar, under the Name of *Reſiné.* And the ſame thing is to be underſtood as practicable in Malt,

or

or Wort, and the ſweet Juices of all Vegetables that afford a Wine by Fermentation *.

11. Hence therefore we may derive a Set of Rules, for boiling down, or otherwiſe procuring the eſſential Matter of Wines, in a ſmall Bulk, and preſerving it ſound and ſerviceable for many Years, in order to the making of all kinds of Wines, Vinegars, and Brandies; even in Countries, where no Vines grow. And this Diſcovery alſo affords great Light into the true Nature and Uſes of *vinous and acetous Fermentation*. *Rules.*

12. To illuſtrate and confirm this Diſcovery by an Example, upon the footing of the preſent Experiment: Take two hundred weight and a half of double-refined Sugar; put it into a Pipe, or Wine-Veſſel of two Hogſheads; fill the Veſſel within four Gallons of the top with pure Spring-Water; ſet it in a warm Place, or Wine-Vault; add three or four Pounds of freſh Ale-Yeaſt, or rather of new Wine-Yeaſt; and the Liquor in a few Month's time will ferment into a ſound, colourleſs, and flavourleſs Wine, and remain ſuſceptible of any Colour or Flavour at pleaſure; ſo as with the Stain called *Turnſol*, to be made of the true Claret-Colour; and with a little eſſential vegetable Oil, of any particular Flavour required. And this is deliver'd as an Experiment that ſucceeds to great perfection; ſo as to ſhew a rational and practicable Method of producing Wines in the Sugar Colonies, or elſewhere, that ſhall rival thoſe of *France*, *Italy*, or *Spain*; and if the Nature of Fermentation be well underſtood, the Proceſs may be greatly ſhorten'd in point of time, and other Advantages. *Practice.*

13. And ſo much for the Uſe of our preſent Experiment, with regard to Trade, and Oeconomy; *Uſes to Trade.*

* See an Eſſay lately publiſhed upon the Art of *Brewing* and *Diſtillation*. See alſo hereafter, *Lect.* XI. *paſſim*.

nomy; its Philoſophical Uſes are no leſs conſiderable. And firſt, it ſhews that the proper fermenting Matter of every fermentable Subject is but ſmall, compared with the quantity of Wine it affords. Thus, for example, we ſee that four Pounds of Raiſins may be diluted, and fermented, with eight Pounds of Water, into what is accounted a tolerably ſtrong Wine. And yet even Raiſins themſelves contain a large Proportion of Water, beſides their direct ſaccharine Subſtance; which ſaccharine Subſtance is reducible to a dry form, as we find in Sugar. And whoever would thoroughly enquire into the Nature, the Uſes, and Means of improving *vinous* and *acetous* Fermentation, cannot perhaps do better than to chuſe Sugar for his Subject; a chemical Analyſis whereof will ſhew the Principles neceſſarily required in this Operation. Theſe Principles appear to be an acid Salt, an Oil, and Earth ſo united together, as to be capable of diſſolving perfectly in Water.

*To Philoſophy.*

14. Hence alſo we ſee the phyſical Cauſe of the fermentable Nature of River-Waters; which being kept in cloſe Casks, have been obſerved to ferment, and their Vapor, or Spirit, to take fire at the approach of a Candle. For much vegetable Matter, as Leaves, Graſs, the Juices of Plants, *&c.* being by the Rains waſhed down into Rivers; ſuch vegetable Matters muſt neceſſarily there run into a fermenting State; as Raiſins do by the addition of Water: the running or fluxile State of the Rivers being no hindrance to this fermentative Motion, after it is once begun by Stagnation. For we ſee that Beer and new Wine will ferment afreſh upon being ſhook, and carried upon Drays, or Carts.

15. All fermentable Bodies do not require *Ferments*, to begin their Motion of Fermentation

Raiſins

Raiſins, we ſee, require none: much leſs does the freſh expreſſed Juice of the Grape; or other vegetable Juices, in the Summer-Seaſon, or in a warm Air. But all ſweet vegetable Juices, that have felt much of the Fire, as Treacle-Wort high boiled, Rob of Malt, Rob of Elder, or the like, uſually require a conſiderable Proportion of a vinous Ferment, to make them work. And, in general, Ferments are no more than Matters already in the Act of Fermentation; or that ſoon run into this Act: Of the firſt kind are the Flowers of Wine, Yeaſt, fermenting Beer, or fermenting Wine, *&c.* and of the ſecond, are the new expreſſed vegetable Juices of Summer-Fruits, *&c.*

16. Water, we find, is abſolutely neceſſary to begin and procure a fermentative Motion in vegetable Subſtances. For Raiſins, or Sugar, being kept dry, will never ferment. And this holds univerſally, of all the Subjects of *vinous* and *acetous Fermentation.* Whence Water is an Inſtrument that muſt be neceſſarily employed in theſe kinds of Fermentation, whether natural, or artificial *.

17. As the Water, which naturally, and in large quantities, perſpires from the Surface of Vegetables, eſpecially in hot Climates, does not go off pure, but carries along with it a conſiderable Proportion of fermentable Matter into the Atmoſphere †; there may be an actually vinous Fermentation, begun and carried on in certain Parts of that Region; eſpecially where the Winds are ſtill, or the Air ſtagnant. And what phyſical Effects and Uſes this Fermentation, in the Atmoſphere, may have, ſcarce ſeem to have been conſider'd; nor ſhould they be raſhly judged of, 'till a more thorough Enquiry is made. At *Schiedam*

* See *Lect.* I, III, V, *paſſim.*
† See *Lect.* V.

*Schiedam* in *Holland*, a larger quantity of inflammable Spirit is said to be obtained from Malt, than in any other Place, where there are fewer Malt-Stillers. This is probably owing to the Air of that Place being impregnated with the fermenting Vapours, that continually exhale from their numerous fermenting Backs and Stills. And the same is found to hold proportionably of Wines fermented in large Vaults, or Cellars; where many Casks of Wine are at once, or somewhat successively, set to work.

18. Warmth, with the free Admission of the external Air, is necessary to expedite the Action of vinous Fermentation; for if our Raisins and Water were to stand either in a very cold Place, or be kept entirely from the Access of the common atmospherical Air; either no Fermentation, or a very small and slow one, would ensue; as has been experienced.

19. The Lees remaining at the bottom of the Cask, in our present Experiment, are, if used fresh, a true kind of *Ferment*, that will set any less fermentable Subject at work, and determine its Fermentation for the vinous kind. They contain a large Proportion of essential Oil, and some Tartar. And hence we see, that vinous Fermentation consists, *first*, in an intestine Struggle, or Commotion of the Fluid; and, *secondly*, in a Separation of a grosser part, which did not appear in that form before.

## EXPERIMENT II.

*The Nature, Effects, and Use of acetous Fermentation: or the Method of turning vegetable Matters into Vinegar.*

*Vinegar made.*

20. We took the Skins of the Raisins, and the Sediment left behind, after a Wine was made in the

the manner of the preceding Experiment; and poured three or four times their own quantity of boiling Water upon them; ſo as to make a thin aqueous Mixture. Then ſet the containing Caſk, looſely cover'd, in a warmer Place than was uſed for the Wine; and found the Liquor, in a few Weeks time, became a clear and ſound Vinegar; which being drawn off from its Sediment, and preſerved in another Caſk, well ſtopp'd down, long continued perfect, and fit for Uſe.

21. This Experiment ſhews us a cheap and ready way of making Vinegar from refuſe Materials; ſuch as the Huſks of Grapes, decay'd Raiſins, the Lees of Wine, Grounds of Ale, Beer, *&c.* which are frequently thrown away as uſeleſs. Thus in many Wine-Countries, the *Marc*, Rape, or dry Preſſings of the Grapes are thrown in heaps, and ſuffer'd to putrify unregarded; tho' capable of affording as good Vinegar, as the Wine itſelf. In ſome places, they bury Copper-Plates in theſe Huſks, in order to make Verdigreaſe; but this Practice ſeems chiefly confined to the Southern Parts of *France*. Our preſent Experiment ſhews us how to convert them to another Uſe; and the Direction extends to all the Matters, that have once undergone, or are fit to undergo, a vinous Fermentation, for that all ſuch Matters will afford Vinegar. Thus all our Summer-Fruits in *England*, even Black-berries; all the refuſe Waſhings of a Sugar-Houſe, Cyder-Preſſings, or the like, will make Vinegar, by means of Water, the open Air, and Warmth. *The Experiment extended.*

22. The whole Proceſs, whereby this Change is effected, deſerves to be attentively conſider'd. And firſt, the Liquor to be thus changed, being kept warmer than in vinous Fermentation, it in a few days begins to grow thick, or turbid; and without throwing up Bubbles, or making any *The Proceſs phyſically conſider'd.*

any conſiderable Tumult, as happens in vinous Fermentation, depoſits a copious Sediment. The Effect of this Separation begins to appear firſt on the Surface of the Liquor, which gathers a white Skin, that daily increaſes in Thickneſs, 'till at length it becomes like Leather; and now, if continued longer in this State, the Skin turns blue, or green, and would at laſt grow ſolid, and putrefy: therefore in keeping down this Skin as it grows, and thruſting it gently down to the bottom of the Veſſel, conſiſts much of the Art of Vinegar-making, eſpecially from Malt.

*Larger Obſervations.*

23. It is to be particularly obſerved, that if the Wine of our firſt Experiment were not bunged down, when arrived at its vinous State; but ſuffer'd ſtill to remain open and expoſed to a warm Air, it would ſpontaneouſly become Vinegar; and the ſooner, if a ſomewhat greater Degree of Heat than ſerved for the making of Wine, were employed. Whence we might have uſed the Wine of our firſt Experiment for this purpoſe, as well as have added Water to the Huſks, and Sediment, or Lees; but we choſe the latter way, to ſhew that every ſuch refuſe Matters will afford Vinegar; and again, to intimate how far the Art of Vinegar-making may be ſtill improved, both in *England* where they brew a Wort from Malt, and in ſome Wine-Countries, where they make their beſt Wines into Vinegars.

24. What we would chiefly obſerve, for the preſent, is, that *acetous Fermentation* requires a ſtronger Heat than the *vinous*; and that Wines having once finiſhed their Fermentation, as Wines, do not naturally ſtop there; but unleſs prevented, by the Care of the Operator, proceed directly on to *Vinegars*; where again they make

no

no Stop, but unleſs prevented here alſo, ſpontaneouſly go on to Vappidity, Ropineſs, Mouldineſs, and Putrefaction. From which larger Obſervation we would deduce this Axiom; That, to ſpeak philoſophically, *the Intention, or Tendency of Nature, is to proceed from the very Beginning of vinous Fermentation, directly, in one continued Series, to Putrefaction; and thence again to a new Generation:* which appears to be the grand Circle, wherein all natural things are moved; and all the Phyſical, or rather Chemical Phænomena of the Globe produced.

25. And hence we ſee, by the interpoſition of Man, how this general Proceſs of Nature may be ſtopped at different times, with different Views; ſo as to procure to ourſelves Wines, Vinegars, and, as will appear hereafter *, particular Salts and Oils. *Corollaries.*

26. Another Corollary from the larger Obſervation above laid down, is, that the word *Fermentation* has been uſually applied to ſignify only a ſmall Part of this grand Operation of Nature. Thus one limits the Word to the Production of Wines; another, to the Production of Wines, and Vinegars; and ſome would diſtinguiſh it from *Putrefaction:* whereas either the Term *Fermentation*, or ſome other, ſhould be made general; and denote the *Genus*, or *univerſal Fermentation*; whereof *Vinification*, *Acetification*, and *Putrefaction*, are only Species. At leaſt, we ſhould thus attempt to follow, and expreſs Nature in the Facts that are obſerved; and not proceed, in an arbitrary, narrow, or inadequate manner, to impoſe Words, and dreſs out Nature according to particular Hypotheſes and Conceits. But the Obſervation itſelf, whereon this Doctrine

is

* See below, *Exp.* VI, VII.

is founded, being of moment to the right underſtanding of the whole Affair of Fermentation and Putrefaction; we proceed to illuſtrate and confirm the laſt part of it by an Experiment, as the two former Parts have been already *.

## EXPERIMENT III.

*That Wines, and Vinegars, or all fermented vegetable Juices, have a natural Tendency to Putrefaction.*

*Vappidity and Putrefaction ſucceed Fermentation.*

27. We took a Gallon of thick, muddy Vinegar, produced after the manner of our ſecond Experiment; letting it ſtand open, in a hotter Place than was required to make it Vinegar, it became in a few days a vappid, nauſeous, and putrefied Liquor, throwing up a large quantity of a dry powdry Subſtance to the top, and depoſiting a leſs quantity of a groſſer Matter at the bottom. Soon after which, the Body of the Liquor became clear again.

28. We might ſhorten the preſent Experiment, or ſave the trouble of making either a Wine, or a Vinegar, to ſhew it. For if a quantity of *Muſt*, were ſet in an open Veſſel, in a hot Stove-Room, where the Air had free Acceſs, the Work would ſoon be performed; and the putrified Liquor be produced almoſt at once; without ſtopping at the State either of Wine or Vinegar; according to the larger Obſervation deliver'd above †.

*Phyſical Uſe of the Experiment.*

29. The preſent Experiment has a conſiderable philoſophical Uſe; as affording Light to the Underſtanding, and leading us far into a Knowledge of our Subject. And (1.) it gives us the phyſical Reaſon why Wines, and Vinegars, unleſs

* See *Exp.* I. II.

† §. 24, 26.

unleſs made exceeding ſtrong, will not keep, but corrupt and putrefy in hot Countries. For the Heat being there ſo great, as to keep the lighter feculent Parts of thoſe Liquors ſuſpended for ſome time in the Body of the Liquor; Corruption (which proceeds from a tumultuary Motion of all the different Parts of a compound Body together *) neceſſarily enſues.

30. (2.) Hence alſo we learn the phyſical Reaſon why Wines and Vinegars require to be rack'd from their Lees, in order to preſerve them ſound, or keep them from running into Putrefaction, to which we find they are ſtrongly inclin'd; the Tendency of Nature being ever conſtant in urging them to that State. And the Caſe appears to be much the ſame in animal, and even mineral Subſtances; as we ſhall ſee hereafter †. *Practical Oeconomical Uſes.*

31. (3.) This Experiment, therefore, furniſhes us with a Rule for preſerving vegetable Liquors from the laſt Stage of Fermentation, that is, Putrefaction, or Corruption; *viz.* by firſt clarifying, and afterwards ſecuring and defending them from the open Air; and too much Heat. Thus, for example, we can preſerve the natural Juices of Quinces, Oranges, Lemons, Plants, *&c.* ſound and uncorrupt; by firſt clearing them of their groſſer Parts by the Filtre; or in ſome Caſes by boiling and common ſtraining; then putting them up in Glaſſes; pouring Oil on the top, and ſetting them in a cool Place. And in the ſame manner we find ſome of the more delicate and curious Wines are long preſerved ſound and ſprightly: for the groſſer Feculencies being firſt removed, the Oil poured on the top prevents the external Air from entring; and by



* See §. 27. and hereafter, *Exp.* VI, and VII. See alſo the Lord *Bacon's Sylva Sylvarum paſſim.*

† *Exp.* VII, VIII.

keeping the Glaſſes from the Sun, or open Day, too much Heat does not come at them.

*Phyſical and Chemical Uſe.*

32. (4.) It is here remarkable, what a large Quantity of ſolid, earthy Matter is naturally contained in all fermentable Liquors. Thus, tho' a pellucid Solution of the fineſt Sugar in Water were expoſed to vinous Fermentation; it ſoon grows turbid, throws an earthy Skin to the top, and depoſits much terreſtrial Matter at the bottom, in the form of Lees. If the Wine be now drawn off clear, and expoſed to acetous Fermentation; here again it throws off much terreſtrial Matter, both in the form of a Skin at top, and Lees at the bottom. Thirdly, if tranſparent Vinegar be expoſed to putrefactive Fermentation; here again it ſeparates a conſiderable Quantity of Earth, both at the bottom and top. Which ſhews that the ſeparation of a groſs Matter is eſſential to theſe ſeveral kinds of Fermentation, and that a copious Earth may lie concealed in fermentable Juices, and tranſparent Fluids, till it finds an occaſion of manifeſting itſelf to the Senſes.

*The Changes produced by Fermentation.*

33. Before we proceed to animal and mineral Fermentation, it is proper to examine what are the Changes wrought upon vegetable Subjects by vinous and acetous Fermentation. This we may find in ſome meaſure, by comparing Muſt, or a bare Solution of Raiſins in Water, with the Wine and Vinegar which the ſame Muſt, or Raiſins and Water afford, in Vinification and Acetification; and in this Light they may be compared by the direct Uſe of the Senſes: but the internal and eſſential Differences will better appear by a chemical Analyſis, or Diſtillation.

34. Muſt, or a Solution of Raiſins in Water, which makes a kind of *Muſt*, correſponding to the natural Juice of the Grape, is a ſweet, clam-

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my and ſomewhat odorous Fluid; which when committed to Diſtillation, affords not the leaſt inflammable Spirit. But after having paſſed thro' the Courſe of vinous Fermentation, it acquires ſeveral Properties it had not before. For example, it is more tranſparent, and thin; loſes of its Sweetneſs, has ſome Degree of Acidity and Roughneſs; proves more odorous, and affords a large Proportion of *inflammable Spirit*; as appears by the following Experiment.

## Experiment IV.

*That vinous Fermentation produces an inflammable Spirit.*

35. We took three Gallons of new Wine, procured from Raiſins and Water, in the manner of our firſt Experiment, and committed it to the Alembic or Still, which being made to work gently, till the Liquor that came over being thrown upon the hot Still-Head, wou'd no longer take fire, by applying the Flame of a Candle to the riſing Vapour; we thus obtain'd a conſiderable Proportion of *Brandy*, and a weaker *Spirit*. *Inflammable Spirit obtain'd.*

36. This Experiment ſhews us the common Method of making Brandies in Wine-Countries, or a Spirit, from Malt, Melaſſes, Cyder, *&c.* in others. For the fineſt *French*, and *Rheniſh* Brandies, the Rums and the Arracks of the *Indies*, are obtained in the manner of this Experiment; all of them being uſually diſtill'd a ſecond time over, and *made up*, as they call it, with Water, or the weak aqueous Liquor of the ſecond Running, as in our preſent Experiment; to a certain Strength, or ſuppoſed Standard, term'd ſaleable *Proof*. *Uſe of the Experiment.*

*Proof in Spirits what.*

37. This *Proof* is judged of by the Head, or Crown of Bubbles, rising upon the Surface of the Liquor when shook in a long slender Vial; and by the manner wherein these Bubbles vanish. For if they are too large, and vanish too soon, the Spirit is deem'd above *Proof*; if too small, and they go off too soon, it is said to be below *Proof*. But this is a fallacious Method of judging: because there are certain known ways of making a Spirit bear this Trial, when it is in reality either above or below Proof. For the proper meaning of the word is, that a Proof-Spirit shou'd contain about one half Water, and the other half Alcohol*.

*Philosophical Use.*

38. The philosophical Use of the Experiment, is to shew that an inflammable Spirit is produced, by the Action of vinous Fermentation, from a vegetable Subject, and Water, wherein no Signs of any such Spirit before appear'd. Insomuch, that this may be justly esteem'd the Criterion, or inseparable Effect of *vinous Fermentation*.

*Spirit of Wine how obtain'd.*

39. The ways of obtaining this inflammable Spirit to the best advantage, will be consider'd hereafter†. In the mean time, it may be observed, that this Spirit being rectified, to deprive it totally of its aqueous Part, is the *Spirit of Wine*, or Alcohol, whose dissolving Power was shewn in the last Lecture, upon *Menstruums*‡; and this Method is the only one that is known of procuring it. For no Subjects but those of the vegetable Kingdom are found to afford

* See this Matter farther explained in *Lect.* XII. *Exp.* IV. See also *Lect.* I. *Exp.* VII.

† *Lect.* XI. and XII.

‡ See *Lect.* VI. *Exp.* II.

ford it; and that only by means of a previous *vinous Fermentation.*

40. It shou'd likewise be observed, that this *Alcohol* is one of the most essential Parts of Wine: so that, when absent, the Wine loses its Nature; as we see by the Remains of the present Experiment. And when properly used, it is a certain Remedy for most Diseases incident to Wines; as keeping them sound and free from Corruption. Whence we have another Rule for preserving vegetable and animal Substances from Putrefaction. For this Liquor proves a kind of Balsam to them all, and is accordingly used, with success, for preserving even animal Substances, as we see in anatomical Preparations, *&c.* *The Use of the Spirit to Wine.*

## Experiment V.

*That acetous Fermentation abolishes the inflammable Spirit produced by vinous Fermentation.*

41. We put a Quart of sharp Vinegar into a Glass Retort; and distilled, in a Sand-Heat, with Degrees of Fire, into a Glass Receiver; but found not the least inflammable Spirit come over; only an acid aqueous Liquor, commonly called *distilled Vinegar*; which, instead of burning, quenches Fire. *Vinegar yields no Alcohol.*

42. Hence it appears, that acetous Fermentation has a very different Effect from the vinous; and that the inflammable Spirit produced in the former, is either concealed, alter'd, exhaled, destroy'd, or some way abolished, in the latter. A part of this Spirit is unquestionably exhaled by the Heat employ'd in Acetification; yet part also remains behind, under a different Modification; so as to be recovered by Art, in an inflammable Form; as we find by distilling *Use of the Experiment.*

the *Sugar of Lead*; which is only Lead diſſolved in Spirit of Vinegar.

43. Our Experiment affords us a Criterion of acetous Fermentation, as before we had of the vinous. For if an acid uninflammable Liquor comes firſt by Diſtillation over from a vegetable Subject, after Fermentation; this will determine that Fermentation to have been the acetous kind.

44. Thus, therefore, we are plainly led to allow of two very different kinds of Fermentation, in the ſame vegetable Subject; and we conceive that ſome other Species may be found upon due Enquiry.

## EXPERIMENT VI.

*That vegetable Matters change of an animal Nature by a hot Fermentation, or Putrefaction.*

*Putrefaction in Vegetables.*

45. We took a large quantity of freſh and green Cabbage-Leaves; and preſſed them hard down with Weights in an open Tub, bored full of Holes on the Sides, and ſet in a warm place. By ſtanding in this ſtate for ſome days, the Leaves conceived a Heat in the middle, which ſpread to the more external parts, till at length nearly the whole was converted into a pappy, putrefied Subſtance, whoſe conſiſtence wou'd not well ſuffer it to ſeparate into a thicker and a thinner Part. This Subſtance being diſtilled in a Glaſs Retort, afforded the ſame kind of volatile Salt, and Oil, as if it had been an animal Subſtance.

*The Experiment extended.*

46. This Experiment is general; and ſucceeds alike in all tender, juicy, vegetable Subjects: ſo that both the acid and alkaline Tribe of Plants, the ſweet and the bitter, the aſtringent, and emollient, &c. reſolve into this ſame pappy, putrefied

trefied Subſtance. We obſerve it alſo in Hay that is ſtacked wet; in Horſe-litter, thrown on heaps, from the Stable; in the Grape-Husks, or Apple-Pumice, after preſſing for Wine or Cyder; and the larger the Heap, and the greater Weight the Matter it ſuſtains, the greater the Heat; provided the acceſs of the Air be not prevented.

47. Hence we ſee the way employ'd by Nature for changing all *vegetable* into *animal Subſtances*, or of reducing the Matters of both Kingdoms to a ſimilarity; ſo that the one may be uſed for ſeveral Purpoſes inſtead of the other. And thus Nature annually makes large quantities of Compoſt, from the refuſe Weeds, Leaves, Traſh of the Fields, Woods and Gardens: for this vegetable Matter thus putrefying, and becoming ſoft and pulpy, is eaſily diluted by the falling Rains, and thence diſperſed over the Face of a Field, and carried into the Pores of the Earth. And thus the Chemiſt, from ſuch putrefied vegetable Subjects, may, by Diſtillation, procure volatile Salts and volatile Spirits; hardly to be diſtinguiſhed from thoſe of Hartshorn, *&c.* at leaſt the volatile Salt and Spirit ſo obtained, might ſerve for the making of Sal-Armoniac, along with Sea-Salt. For it appears, that the Matter of the fixed Salt in Vegetables is by this Operation truly volatilized. Whence not a Grain of fixed Salt can be procured from the largeſt quantity of this putrefied Matter; provided the Operation were compleatly performed. *In Uſe.*

48. This Experiment has various Uſes; not only in Trades, but alſo in natural Philoſophy and Medicine. And firſt, it ſhews an artificial as well as natural Method of converting any, or all of the different Subjects of the vegetable *In Trade.*

Tribe into the ſame undiſtinguiſhable Subſtance; thus totally deſtroying all the ſpecific Differences which before diſcriminated that great Variety. And the ſame Obſervation reaches alſo to animal Bodies, as we ſhall ſee hereafter *.

*In the animal Oeconomy.*

49. It alſo affords conſiderable Light into the affair of animal Digeſtion, as performed in the Stomach and Inteſtines; it ſhews us the Nature of Gangrenes, Mortifications, and carious Bones in the Body; and the phyſical Reaſon why no fixed Salt is found in the Blood, Bones, or Fleſh. All which particulars may be farther illuſtrated and confirmed, by conſidering the like Proceſs in an animal Subject.

## II.

### EXPERIMENT VII.

*That animal Bodies naturally undergo a Fermentation, or Putrefaction, after Death.*

*Animal Putrefaction.*

50. If any large animal Body, as that of a Horſe, or a Dog, for example, be expoſed, in a dead ſtate, to the open Air, and the Summer's Sun; it, in a few days, begins to ſwell, purge, and emit a nauſeous Stench. At length, the form of the Carcaſs is deſtroy'd by the Commotion; and reſolved into a putrid, fetid, ſtercoraceous Matter: a large part in the mean time flying off into the Air; ſo as to leave but a ſmall proportion of a mucilaginous pappy Subſtance, which ſoon grows dry, or turns to a kind of Earth. But if a quantity of this Matter were to be collected before it grows dry, and diſtilled, it is ſaid to afford the burning *Phoſphorus*, as putrefied Urine is known to do.

51. This

* Exp. VII.

51. This Experiment or Obſervation is uni- *Extended.*
erſal, and holds equally of Birds, Beaſts, and
iſh. Whence Rivers, the Ocean, and At-
noſphere it ſelf muſt be neceſſarily impregnated
vith fermenting, putrefying, and putrefied Par-
icles; which are mixed with other Matters, and
iſperſed through the immenſe Bodies of thoſe
luids, wherein they undergo ſuch Changes,
whether by uniting with the Salts of the Air and
Ocean, or otherwiſe, as not ordinarily to prove
eſtructive or noxious to the Creatures that in-
abit thoſe Elements. For this putrefied Mat-
er appears to be in itſelf a kind of Poiſon, in-
ecting the Air wherein it ſpreads; ſo as to oc-
aſion peſtilential Diſeaſes near the Places where
reat Battles have been fought; when the un-
uried Carcaſes of the Slain thus reſolve and go
ff into the Atmoſphere. And we have other
nſtances of the poiſonous Nature of putrefied
nimal Subſtances, in rotten Eggs, mortified
leſh, and the like: whence this ſeems to be
nother particular Species of *Fermentation*.

52. It has been diſputed, whether there be a *Fermenta-*
eal Fermentation in the preſent Caſe. But ſup- *tion deter-*
poſing this not a Diſpute about Words, it *min'd.*
hou'd ſeem that there is a proper Species of
ermentation, peculiar to the animal Subjects,
s there is one peculiar to Vegetables. And till
his Point be ſettled, we ſhou'd not lay down
egetable Fermentation, as the Teſt and Stan-
ard of Fermentation in general, and judge of
ll other kinds, according as they approach to, or
ecede from this Standard. For want of di-
tinguiſhing, in this Caſe, all true Fermentation
eems denied to the Blood and Juices, circulating
n a living animal Body; and again, to the Sap
f Vegetables. But, perhaps, were the enquiry
nto Fermentation proſecuted in its full latitude,

and

and not arbitrarily confined to any ſingle Species; many natural and artificial Operations wou'd prove to be actual Fermentations. To ſay, that there is no Fermentation in the Blood, becauſe it affords no inflammable Spirit upon Diſtillation; is in effect the ſame, as to ſay, that Blood is not Wine. Whereas the Queſtion is not, whether there be a *vegetable Fermentation* in the Blood; but whether there be not an *animal one:* the Criterion whereof is the Production of a volatile urinous Salt; as the Production of an inflammable Spirit is the Criterion of vinous Fermentation.

*Chemiſtry of Nature in Bodies.*

53. And here is a Door open'd for enquiring into the Chemiſtry of Nature, as it is exerciſed in the Bodies of Men; ſo as to diſcover the natural Means whereby vegetable Subſtances taken in at the Mouth, by the way of Aliment, are prevented from running into vinous or acetous Fermentation; but are, on the contrary, changed into a balſamic, unctuous and milky Liquor, or Chyle, that turns red in the Arteries, recruits the Blood, and ſupplies the Body. For all this ſeems to be the Effect of a peculiar *animal Fermentation*; the Laws and Proceſs whereof are little conſider'd. And in this view, the ſeveral Juices of the Body, as the Saliva, Bile, Pancreatic Juice, *&c.* may be regarded as animal *Menſtruums*; acted upon, and made to act in the Body by determinate Motions, for determinate Ends.

## III.

### EXPERIMENT VIII.

*That there may be a kind of Fermentation, in mineral and metallic Bodies.*

*Mineral Fermentation.*

54. We took an Ounce of Lead, and as much Biſmuth, and melted them together in an Iron Ladle;

Ladle; then heating two Ounces of Quickſilver, n another Ladle, we mixed all the three me-tallic Matters together, as an Amalgam; which, when cold, appeared perfectly uniform, or homogeneous; and totally paſſed thro' the Pores of Leather, in a running form. But this Mixture being ſuffer'd to cool, and ſtand quiet for ſome hours; a groſs Matter ſeparated from t by degrees, and floated upon the reſt; which was left ſo thin and fluid, as to paſs through Leather; and leave the groſs metallic Matter behind.

*The Experiment extended.*

55. Hence it ſhou'd ſeem, that even metallic Matters may have their peculiar Fermentations, as well as vegetable and animal Subjects. For when the preſent Experiment comes to be carefully conſider'd, it appears to have all the requiſites of Fermentation. For here is, (1.) a fluid Form, (2.) an uniform Matter, (3.) an inteſtine Motion, and (4.) an actual Separation of a groſſer Matter; leaving a thinner behind. All which particulars we have found to hold in the ſeveral Species of Fermentation above conſider'd.

56. There are many more Inſtances of an apparent Fermentation in mineral Bodies; one or two whereof, it may be proper to mention. Thus, if an aqueous Solution of the common green Vitriol be, in the Summer-time, expoſed to the Air, and kept continually ſupplied with freſh Water; as the former exhales, the groſſer metallic Part of the Vitriol will ſubſide, and the reſt gradually ſhoot upwards all round the Veſſel, in form of an unctuous, cruſty Matter; till the whole Body of the Vitriol is thus ſucceſſively alter'd; ſo as that the Part ſhot into the cruſty, unctuous Form, will neither become Vitriol again, nor corrode any freſh Metal: and in all other reſpects it appears a different thing from

from Vitriol. And hence, ſeem to proceed the Complaints of the Makers of Vitriol, that in rainy, windy and cloudy Weather, their Vitriol-Stones, which lie open to the Air, will not ſometimes yield a ſolid cryſtalline Vitriol; but only an unctuous Matter. This may therefore appear to be a Fermentation in all its Forms; as being attended with a ſpontaneous inteſtine Motion; a ſpontaneous Separation of conſtituent Parts; and a remarkable Alteration of the Subject.

57. It alſo makes to the preſent purpoſe, that ſolid and hard Pyrites, or Vitriol-Stones, being expoſed to the Air, and moiſten'd with Water; will, like a vegetable Subject*, grow hot, fume, and even take fire; as was obſerved in our fourth Lecture; and afterwards afford Vitriol; a thing very different from the Stones themſelves†. So that, upon the whole, we may conclude, that in a proper Senſe, there is an actual *Fermentation* exerciſed, not only in the vegetable and animal, but alſo in the mineral Kingdom.

## V.

### AXIOMS *and* CANONS.

1. All the Inſtances being duly conſider'd, and a large View of things taken in; we may define *Fermentation*, in general, a ſenſible internal Motion of the conſtituent Particles of a moiſt, fluid, mixt or compound Body; by the Continuance of which Motion, theſe Particles are gradually removed from their former Situation, or Combination; and again, after ſome viſible Separation is made, joined together, in a different Order and Arrangement. And thus the whole

* See above, *Exp.* VI.

† See *Lect.* IV. *Exp.* V.

whole Proceſs of Fermentation conſiſts of two different Operations, *viz.* an *Analytical* one, whereby the Particles are reſolved; and a *Synthetical* one, whereby they are new ranged. And that whenever theſe two different Effects are found to be produced, in direct Sequence, with the Circumſtances above deſcribed; we need not ſcruple to call the Operation by the name of *Fermentation*; whether it happen in the Blood, or other animal, vegetable, or mineral Subſtances *.

2. That all ſeparable, mixt or compound Bodies may be the Subjects of this general Operation; but that the eaſier they are ſeparable by means of Water, Air, and Heat, the more readily they ferment †. Thus the ſweet or ſaccharine part of Malt, more readily diſſolving in warm Water, ferments eaſier than unmalted Corn, which is more clammy, and will not diſſolve ſo ſoon. And hence the Fleſh of animal Bodies putrifies ſooner than the Bones. And this appears to hold in all Inſtances ‡.

3. That this general Fermentation is diviſible into many diſtinct Species; particularly into *Vegetable*, *Animal* and *Mineral* ‖: The vegetable Kind again into *Vinous*, *Acetous*, and *Putrefactive*; the Vinous again into Mucilaginous, Mouldy and Putrefactive; and ſo of the Acetous, *&c.* Whence we may deduce a *Canon* for adjuſting all the different Species of Fermentation; which being once done, might put an end to infinite hypothetical Diſputes upon this ſubject; and lead to farther Diſcoveries, both in Nature and Art.

4. That

* See the whole Lecture, *paſſim*.
† See *Exp.* I. VI.
‡ See *Exp.* I. VI. VII.
‖ See the whole Lecture, *paſſim*.

4. That it is in the power of Man to prevent, ſtop and regulate theſe natural Operations at any point of time aſſign'd. For it is thus we come by our Wines, and Vinegars. It is thus that Men have diſcover'd the Art of Embalming. 'Tis thus we preſerve many vegetable and animal Juices, in their natural or unfermented State. 'Tis thus we preſerve Yeaſt and Wine-Lees, (Subjects extremely apt to putrefy.) 'Tis thus we can at any time ſtop the Courſe of vinous Fermentation, and produce a ſweet, or half-fermented Wine. It is thus we cure the Frettings, or other Diſeaſes of Wines; and thus that we ſtop Mortifications in the Body, and Caries in the Bones. And moſt of the Artifices employ'd for theſe purpoſes, depend upon a Knowledge and Regulation of the phyſical Cauſes and Inſtruments that produce that Change; which Cauſes and Inſtruments, as we above diſcover'd, are chiefly, Heat, Moiſture, and the external Air *.

5. That a ſaccharine Matter is the Baſis of Wines, Vinegars, and inflammable Spirits †.

6. That a great Variety of ſound, perfect and wholeſome Wines may be made, in Countries that do not naturally afford Grapes; by a prudent Uſe of Sugar, or Raiſins and Water ‡.

7. That the Matters, called Ferments, are of uſe in beginning, regulating and determining the Species of Fermentation ‖. Thus freſh Yeaſt determines the Fermentation of Wheat-Flower to make our common Bread; which wou'd prove of another kind, with the Flowers or Lees of Vinegar. And thus ſpecific or determinate Fer

* See the whole Lecture, *paſſim*.
† See *Exp.* I. §. 15, &c.
‡ See *Exp.* I.
‖ Ibid.

Ferments have their correſpondent Effects. If Sugar, Honey, Manna, Treacle, or new Wine be added to Vinegar; themſelves are ſoon changed into Vinegar, without ſtopping to make Wine; becauſe the acetous Ferment, or Vinegar overrules them. And ſo Vinegar is ſooneſt made, in a Caſk that has before contained the ſame Liquor. And if the beſt Wine were put into a Caſk that had held putrefied Vinegar, the Wine wou'd not now make Vinegar; but immediately run into Corruption. So great and overruling a Power have ſpecific Ferments: the Uſe whereof is therefore evident; and may afford conſiderable *Rules* in Chemiſtry, practical Philoſophy, and Arts.

8. That the Degrees of Fermentation differ with the Degrees of Heat employ'd *. Thus we ſaw vinous Fermentation required a leſs Degree of Heat than the acetous, the acetous leſs than the putrefactive; which latter may even conſiſt with a Degree of Ignition †.

9. That a particular kind of Fermentation may be carried on in the living Bodies of Animals and Vegetables; which are largely ſupplied with the requiſite Inſtruments of Fermentation, *viz.* Water, Air, and Heat; and in fact both Vegetables and Animals appear to have an inteſtine Motion in all their circulating Fluids; which continually depoſite a groſſer Matter in the Canals and Parts they move through. Whence, by our Definition of Fermentation ‡; this natural Act may be accounted a Species of Fermentation, producing a Change in the nutrimental Matter of Vegetables and Animals, and converting it into their own Subſtance.

10. That

* See *Exp.* I, II, III, IV, V, VI.
† See *Exp.* VI.
‡ See *Ax.* I.

10. That when Vegetables or Animals die, there ſoon begins a different kind of Fermentation in all their Parts; tending not now to the Repair, but to the entire Deſtruction of their organical Veſſels; the confuſed Mixture of their ſolid Parts and Juices; and a Volatilization of their whole Subſtance*.

11. That dry or ſolid Bodies cannot, in that State, undergo a proper Fermentation: for tho' they may in that State be ſeparated into minute Particles; yet they cannot range themſelves together in any new Order; nor depoſite a groſſer Part, without being agitated by ſome Fluid; or, for ſome time, ſuſpended therein. And hence, in over-heated Mines, the Ore is thus *analytically* deſtroy'd; and cannot range itſelf into a metalline, or any other regular Order again, for want of the requiſite Moiſture or Fluidity; whence the Matter appears like a Heap of rotten Earth, or what the Miners call *Dead Metal*†, of which we have a remarkable Inſtance in the over-heated or fired Mixture of Sulphur and Iron-Filings.

12. That the terreſtrial, marine and atmoſpherical Regions have each their proper *Fermentation*; different in kind, and ſubdiviſible into particular Species; whereby the Changes of all Bodies one into another are naturally performed‡. And that in imitation hereof, by a thorough Knowledge of the natural Agents that produce theſe grand Effects, Art likewiſe may produce extraordinary Changes in Bodies‖.

LEC

* See *Exp.* V. VI.

† See *Exp.* VIII.

‡ See the preceding Lectures upon the *Elements*. S alſo that upon *Menſtruums*, and the ſeveral Experiments the preſent.

‖ See *Lect.* I. *paſſim*.

# LECTURE VIII.

CONTAINING,

Analytical Chemiſtry; *or, the Art of Analyſing Vegetable, Animal and Mineral Subſtances; and reſolving them into different Parts, or Principles.*

## I.

*Subject.*

1. AS the whole of Chemiſtry may be comprehended under the Art of reſolving Bodies into their Principles, and of compoſing new Compounds from theſe Principles; by means of the common Elements, Fire, Air, Water, Earth, and particular *Menſtruums*; we ſhall endeavour in our preſent Lecture, to enquire into the Buſineſs of Chemical Reſolution, in the vegetable, animal and mineral Kingdoms; with a View to diſcover what uſeful *Principles* may be thence obtained: intending, in our next Lecture, to conſider the correlative Buſineſs of Compoſition; ſo as in the two to give a ſummary Account of the Nature, Office, and Uſe, both of analytical and ſynthetical Chemiſtry: the one whereof takes Bodies to pieces, or reduces them to their component Matters; and the other by putting theſe Matters or different Pieces together again, in various Manners, forms a large Set of new Productions, that wou'd be unknown to Nature, without the interpoſition of Art. And ſuch Productions, for inſtance, are, *Brandy*, *Soap*, *Glaſs*, *Vitriol*, &c.

*Principles what.*

2. But before we enter upon the Enquiry itſelf, 'tis neceſſary we ſhou'd diſtinctly explain our

our Meaning of the Word *Principles*; about which, many Diſputes have been raiſed. We muſt therefore obſerve, that the more intelligent among the modern Chemiſts do not underſtand by *Principles* the original Particles of Matter, whereof all Bodies are by the mathematical and mechanical Philoſophers ſuppoſed to conſiſt. Theſe Particles remain undiſcernable to the Senſe, tho' aſſiſted with the moſt finiſhed Inſtruments; nor have their Figures, and original Differences been determined by a juſt Induction. Leaving, therefore, to other Philoſophers the ſublimer Diſquiſition of primary Corpuſcles, or Atoms, whereof many Bodies and Worlds have been formed in the Fancy; genuine Chemiſtry contents itſelf with groſſer Principles, which are evident to the Senſe, and known to produce Effects in the way of corporeal Inſtruments. And theſe groſſer Principles are every way ſufficient to anſwer the Purpoſe of philoſophical Chemiſtry; which wholly conſiſts in Experiment, and the Explanation of Facts, and ſenſible Operations. Where, by the way, it may be obſerved, that the Art of Chemiſtry is an Art extremely well ſuited to Men; as it requires nothing more than the uſe of ſuch Faculties as they evidently find themſelves poſſeſſed of. But when once we leave the Oracles of Senſe, and introduce metaphyſical Speculations and Notions into Chemiſtry; 'tis then that Chemiſtry becomes a corrupt Fountain of Hypotheſis and Illuſion. To rectify Chemiſtry, therefore, the Rule is to keep cloſe to Information of the Senſes, the Laws of Induction, and the Uſe of material and ſenſible *Principles*.

3. Theſe ſenſible Principles, ſo far as we know them, are ſignificantly expreſs'd by the common Words, *Water*, *Earth*, *Salt*, *Sulphur*, and *Mercury*:

*Mercury:* to which might be added the Air, if a way were known to fix it, ſo as to render it more ſenſible, tangible, and corporeal*.

4. By *Water*, we underſtand a ſenſible tranſparent Liquor without Taſte, or Odour, that freezes with a certain Degree of Cold, and liquifies from that State, with a certain Degree of Heat; that extinguiſhes Fire, *&c.* This is otherwiſe called, by the Chemiſts, *Phlegm*. *Water.*

5. By *Earth*, we underſtand an inſipid, dry powdry Subſtance, that will neither diſſolve in Water, nor burn away in a ſtrong Fire; but, with the addition of fixed Salt, melts into Glaſs. *Earth.*

6. By *Salt*, we underſtand any ſenſible Body, that readily diſſolves in Water, taſtes ſharp or pungent upon the Tongue, and has a great diſpoſition to unite with Earth, ſo as to appear in a ſolid Form; as in common Salt, Alum, *&c.* *Salt.*

7. By *Sulphur*, we mean any Matter that will readily burn and diſappear in the Fire; and that will not eaſily, or of itſelf, mix with Water. *Sulphur.*

8. And laſtly, by *Mercury*, we underſtand a ſenſible Body, that has the Fluidity, Gravity and Appearance of common Quickſilver. *Mercury.*

9. But we do not lay down theſe Definitions as adequate, only to give ſome ſenſible Marks whereby they may be readily known and diſtinguiſhed for ordinary uſe. Juſt Definitions can only be drawn from a full and perfect Diſcovery of the Nature and Properties of Bodies, which we are far from knowing; nor do we uſually meet with any of theſe Principles in a pure and perfect State, unmixed with other Bodies. When they appear to the Senſes to be thus far purified, they are the Principles we



* See *Lect.* III. *Exp.* X.

mean; or what we emphatically call the *Chemical Principles*; tho' they may be every one of them deſtructible in that Form: but then they ceaſe to be chemical Principles.

10. And thus we have endeavoured to ſettle the chemical Meaning of the word *Principles*, and lay down Marks, or Criterions for diſcovering and diſtinguiſhing them, when we ſhall meet with them hereafter, in the following Experiments.

11. Theſe Experiments we ſhall attempt to make as general as we can; and give an Example in each of the three Kingdoms, as they are called; *viz.* the Vegetable, Animal and Mineral.

## EXPERIMENT I.

*That Vegetables, are reſolvable by Fire, into four of the chemical Principles, viz.* Water, Oil, Salt *and* Earth.

*Wormwood analyſed.*

12. We took two Pounds of common Wormwood cut ſmall, and put it into a Glaſs Retort, in a Sand-Heat; and diſtilling with Degrees of Fire, and a frequent change of Receivers, we obtained, (1.) an aqueous Liquor, and (2.) an Oil. Then taking out the Remainder; and burning, or calcining it, in the open Air, it turned to a grey kind of Aſhes; which being boiled in fair Water, communicated (3.) a Salt thereto. This Salt we obtained in a dry Form, by letting the Solution ſtand at reſt for ſome time, and afterwards decanting the clear Liquor, and exhaling the ſuperfluous Water. And (4.) we found an earthy Subſtance, remaining at the bottom of the Water, wherein the Aſhes were boiled.

*The Experiment made general.*

13. This Experiment being well attended to, is very inſtructive; and ſhews that the *chemical Prin-*

*Principles* above-mention'd are not imaginary or fictitious Things; but Things palpable, and evident to the Senses. For we have here a Water, an Oil, a Salt, and an Earth, all afforded us by a vegetable Subject. And the Experiment may be made general without much variation: for all the vegetable Subjects hitherto examined, in this manner, resolve themselves into the same general Principles; that differ only (1.) in respect of the kind of Salt; which in some is more volatile, in others more fixed; in some acid, in others alkaline: and (2.) in the Nature or particular Properties of the Oil; which in some Plants is more thin and fluid, in others more gross and viscous, *&c.* But all the Principles thus obtained, agree to the general *Definitions* above laid down*. So that there appears to be no Vegetable in Nature, but what is thus resolvable into Water, Oil, Salt and Earth.

14. To obtain these Principles pure, we must (1.) separate all the Oil that may chance to remain suspended in the *Water*. This is effected to a considerable degree, by the Filtre; which being kept continually filling up, so as that the lighter Oil may not come in contact with the paper, the aqueous Part is thus transmitted tolerably free from Oil. (2.) But still there may remain some small Proportion of oily, and saline Matter therein? If the saline Matter be acid, the way to destroy it, is by mixing a little Chalk, or any pure and fixed alkaline Salt with the Liquor; whereby also, more of the Oil will be set free: so that being now filtred again, and gently distilled with a soft Heat, the aqueous part will rise much purer; and pass for Water in the Judgment of the Senses. (3.) If the Plant *The Water purified.*



* Sect. 4—8.

were alkaline, and an alkaline Salt abound in the aqueous Liquor, let it be made neutral with one that is acid; and thus again the Water may be ſeparated pure, by means of the Filtre, and Re-diſtillation. And this is the Method of manifeſting to the Senſes, that the chemical Principle *Water* is naturally lodged in, and may be ſeparated from all vegetable Subſtances*.

*The Oil purified.*

15. In order to procure the *Sulphur*, or oily Principle, pure; the unctuous Matter obtained, by this general Proceſs, may be waſhed from its adhering Salts, and groſſer Earth, in warm Water; barely by ſhaking them in a Glaſs together; then ſeparating the Oil from the Water, by means of the common ſeparating Glaſs; where, if the Oil be ſpecifically heavier than Water, it ſinks to the Bottom; and may be ſuffer'd to run out firſt; if ſpecifically lighter, it floats a-top, and may by the Finger, applied to the bottom of the Glaſs, or other contrivance, be kept behind; when all the Water and feculent Parts are run from it.

*The Salt purified.*

16. To obtain the ſaline Principle pure; (1.) if it be of the volatile urinous kind, the Matter may be diſſolved in Water; and made to paſs the Filtre; then ſet, in a gentle Heat, to ſublime: for it will thus riſe, and leave the Water behind as being much more volatile than that. (2.) If it be required ſtill purer, the beſt Method hitherto known, is to ſublime it from finely pulverized Chalk; then to ſaturate it with a clear Spirit of Sea-Salt, ſo as to convert it into a true Sal-Ammoniac; which being mixed with Salt of Tartar, and now again ſet to ſublime; the volatile Salt will thus riſe highly purified; ſo as long to retain its Whiteneſs. (3.) But if the ſaline Matter

* See *Lect.* V. *Exp.* I.

Matter obtained, be of the fixed kind; the Method of purifying it, is to dissolve it in fair cold Water; suffer the Solution to subside; then decant the clear Liquor, and evaporate it in a clean Iron-Pan, or Glass Vessel, till, with constant stirring, it becomes dry and white: (4.) or to purify it still farther, and render it perfectly white; let it be put into a clean Crucible; and exposed for a while amidst the flame of burning Charcoal; without melting.

17. Lastly, to obtain the earthy Principle in its purity, let it be thoroughly calcined, boil'd in several Waters, to get out all its Salt; and then dry'd over a clear Fire, or in the Sun. And when these several Operations are perform'd in perfection; 'tis then we obtain what we properly mean by the *chemical Principles of Vegetables.* *The Earth purified.*

18. And tho' it be not always necessary for the Purposes of Chemistry, or the common Calls of Life, to bring these Principles to the Degree of Purity here mention'd; yet there are many Cases that absolutely require them to be so purified; otherwise the Operations wherein they are employ'd may easily miscarry, which we desire shou'd be noted, as one considerable Reason of the Failure of particular Experiments and Operations; both in Chemistry itself, and many of the chemical Arts, particularly the Art of Glass, Distillation, *&c.*

19. The Uses of this leading Experiment are numerous; we shall touch upon a few of them. And first, we may learn from it, that these chemical Principles abound in different Quantities, in different Vegetables, or in the same, at different Seasons, or Times of Growth. Thus, for instance; Olives, Almonds, Mace, *&c.* contain such an Over-Proportion of Oil, to the other *Uses of the Experiment.*

Principles, that it may be copiously got from them barely by Pressure. The Vine in the Spring affords a larger Proportion of fixed alkaline Salt than at any other Season; and the same holds of the Wood usually burnt for Pot-ash. And thus we find, that the aqueous and saline Principles preside in Vegetables in the Spring, but the oily in the Summer and Autumn: that all young Plants abound more with Water, than such as are full grown; and that Oil is most plentifully contained in the oldest Trees, and those of the colder Climates. Whence we are directed to the proper Times and Seasons, and Places for felling the Timber design'd for Pitch, Pot-ash, Fewel and Charcoal.

20. By applying this Experiment to different Vegetables, it has been found that Vegetables are naturally distinguishable into two grand Tribes; *viz.* the Acid and the Alkaline; the first affording a volatile Acid, and the other a volatile Alkali, upon dry Distillation. Thus Guaiacum, Cedar, Box, Cinnamon, Cloves, Sorrel, Mint, Baulm, *&c.* afford an Acid; but Garlick, Leeks, Onions, Horse-radish, Scurvy-grass, Mustard, *&c.* afford an Alkali; which, when rectified, is hardly distinguishable from that of animal Substances, so as nearly to resemble the Spirit and Salt of Hartshorn *.

21. This Experiment also shews us the Methods of making or procuring Tar, Charcoal, fixed Salt, and elementary Earth, from Vegetables; four capital Things in Arts and Trades. Tar is the scorched Oil of unctuous Wood, forced out by Fire; as the gross Oil is in the *present Experiment* †. Charcoal is Wood burnt close to

* See *Lect.* VII. *Exp.* VI.
† See also *Lect.* II. *Exp.* III.

to blackness *: Soap, a mixture of fix'd Salt and Oil; Glass, a mixture of Earth and fixed Salt; and elementary Earth makes all the Tests and Copels for refining of Gold and Silver.

22. Again, the present Experiment shews us the Nature of vegetable Fumes; whereby, in the way of animal Curation, Fish and Flesh are long preserved, free from Putrefaction or Corruption. For where-ever green Wood, or any acid vegetable Matter is burnt, the acid Particles go off with the Smoke, and in this Form penetrate and lodge in animal Substances exposed thereto; whereby this Smoke acts upon them in the same manner as the Fume of Spirit of Sea-Salt or Nitre wou'd do. And whether it be not a nitrous Acid which thus tinges the Hams, Herrings, *&c.* red in drying, we recommend to farther examination.

23. Our Experiment also confirms what was before observ'd †, that the force of Fire is not sufficient to reduce a vegetable Substance to Ashes, without the help of the Air; and that so long as the fixed Oil, which causes the Blackness, remains in a vegetable Coal, it will afford no fixed Salt by Decoction in Water ‡. Whence we have a Rule in the making of Pot-ash, and all the fixed Salts to advantage, thoroughly to calcine the Subject, so as to leave no fixed Oil behind.

24. And hence we are also instructed in the physical Nature of a vegetable Coal; and see how it may have such considerable Effects upon Metals, in the way of a *Flux*; since we find it contains a fixed Oil, firmly united to the Matter of a fixed Alkali; whence, to use this Coal as a Flux, is the same thing as to use a fixed Salt in-

* See also *Lect.* II. III.
† *Lect.* II. *Exp.* IV.
‡ See *Lect.* II. *Exp.* IV.

intimately united with a fixed Oil, which may operate powerfully upon Ores, as we have formerly ſhewn*. And ſo much for the *Analyſis* of Vegetables.

II.

EXPERIMENT II.

*That animal Matters are reſolvable by Fire, into the four chemical Principles,* Water, Oil, Salt *and* Earth.

*Bone analyſed.* 25. We took four Pounds of animal Bones, that had been well boiled, to get out their Marrow or Fat, and then thoroughly dried again; and breaking them into ſmall Lumps, we put them, dry as they were, into an earthen Retort, whereto a Glaſs Receiver being luted; we diſtilled, with Degrees of Heat, in a naked Fire. There firſt came over in Drops an aqueous limpid Liquor, which we reſerved apart, by changing the Receiver. Then increaſing the Fire, there came over white Fumes; a volatile Salt, and a quantity of Oil. The Veſſels being ſuffer'd to cool, we found the Bones turned black in the Retort; but being calcined in a naked Fire, with the admiſſion of the free Air; they there turned white. Then boiling theſe white Aſhes in Water, we found by Evaporation that they communicated no fixed alkaline Salt thereto.

*The Experiment extended.* 26. This Experiment is general, or ſucceeds, with little variation, in all other animal Subjects; whether they be Fleſh, Blood, Serum, Fiſh, Birds, Snakes, the Whites of Eggs; Horn, Hair, Hoofs, Silk, or the like: the principal Differences being only, that theſe Subſtances reſpectively

* See *Lect.* I. *Exp.* III. See alſo hereafter the Lectures upon *Mineralogy* and *Metallurgy*.

respectively contain more or less Earth, Water, Salt and Oil. Thus the Blood being distilled in its natural State, or as it is drawn from the Vein of a healthy Person, will yield about seven-eighths of quantity in Water. And if any animal Subject be not well purged of its Oil, by boiling in common Water, before it is committed to distillation; it thence affords a greater quantity of a burnt empyreumatical Oil, that strongly taints and impregnates the volatile Salt and Water, with a nauseous Scent and Taste; which are hard to get off, even by repeated Rectifications.

27. The Principles separated by the present Experiment, appear to be, in general, the same, as with those before gained from a vegetable Subject. They may be separately purified and made Elementary, after the same Methods as we there laid down. And thus, by comparing the Productions of both Processes together, we shall find that we have a Water, an Oil, a Salt, and an Earth in both Cases. *Its Uses.*

28. The two Waters seem scarce to differ, when reduced to the same Degree of Purity; no more do the Oils and the Earths; but all the Salt in the present Case is volatile; the Ashes containing no fixed Salt at all: whence this appears to be the principal chemical Difference betwixt vegetable and animal Subjects, that the vegetable kind yield a fixed Salt by Calcination; and the animal kind, one that is volatile by Distillation. But this holds only of the acid Species of Vegetables; for the alkaline Species yields little or no fixed Salt upon Calcination. So that betwixt the alkaline Tribe of Vegetables, and the whole animal Kingdom, there seems to be little difference; neither in this, or any other chemical Respect*. But tho' some Difference shou'd

* See *Lect.* VII. *Exp.* VI.

ſhou'd be found betwixt the animal and vegetable Oils, as there is thought to be in the making of Soap, and ſome other Inſtances; yet the Principles of animal and vegetable Subjects may be juſtly reputed the ſame; as both equally agree to our general Definitions of Water, Oil, Salt and Earth *. But when the ſeveral Principles of Vegetables and Animals are reduced to the ſame Degrees of Purity and Fineneſs; there ſeems, ſo far as our Trials have gone, to be no ſenſible Difference between them. Thus the pure elementary Earth of Vegetables ſerves for the making of Teſts and other Purpoſes, as well as the elementary Earth of Animals: ſolid Soap is made of vegetable Oils, as well as of animal Fats; and the volatile Salt of alkaline Vegetables, or even of acid Vegetables when purified, is not to be diſtinguiſhed from the volatile Salt of Animals, when both are thoroughly purged and purified.

*The animal Principles how purified.*

29. But the Labour and Difficulty required to bring theſe Principles to a high degree of Purity, has proved a chief Cauſe of their being thought different: For we ſee that the Oil tenaciouſly adheres to the volatile animal Salt; and thus adds ſome qualities that do not properly belong to that Salt. But if a volatile animal, and a volatile vegetable Salt, be each ſeparately converted into Sal-Ammoniac, by means of Spirit of Sea-Salt; no ſenſible Difference can be found betwixt them. And thus, if a vegetable Oil, and an animal Oil were equally purified, ſubtilized and freed from all the Matters that do not eſſentially belong to them, they wou'd not ſenſibly differ. At leaſt, this ſeems confirm'd by ſeveral Experiments †.

30. And

* See above, §. 4—8.

† See Dr. *Cox*'s Papers in the *Philoſophical Tranſactions*.

30. And hence some Advantages might be derived to Arts and Trades, by making the Subjects of one Kingdom serve instead of those of the other; where one is cheaper than the other. Thus, we before observed, that a volatile Spirit and Salt, like those of Hartshorn, may be drawn from the alkaline Species of Vegetables, and all putrefied Plants*; at least from Bones purged of their Fat, by boiling in Water. *Farther Uses.*

31. The present Experiment has many other Uses; and among the rest, remarkably shews us how a perfectly dry, insipid, scentless, and solid Body may yield a great Variety of Tastes and Odours, barely by being applied to the Fire. For the impure Water, the volatile Spirit, the Salt and the Oils, have each a particular Taste and Odour. And tho' the Subject itself were fixed, we see it thus affords several volatile Matters. And as this fixed Substance was originally composed of a fluid Matter, we are hence taught that the animal Solids and Fluids have the same common Nature; their Difference only consisting in a greater or less Proportion of Water and Earth. For Blood, upon the like Analysis, affords more Water, and less Earth than Bone.

32. This Experiment likewise shews us, that a Bone may be entirely divested of its Water, Salt and Oil, without losing of its pristine Figure and Dimensions. For after those Principles are separated from it, the elementary Earth, tho' absolutely dry and friable, still hangs together in the natural Form and Figure of the Bone; which thus remains exhausted of all that Matter, which the Fire was able to carry off, without

* See *Lect.* VII. *Exp.* VI.

without affecting the elementary Earth itself. Whence we evidently see, that the use of this elementary Earth, in vegetable and animal Bodies, is to afford a Lodgment, a Support or Skeleton to the other Principles, which are much more dissipable and destructible than itself.

33. And as our Experiment succeeds alike in all animal Matters, and even in the Gelly, obtained from a Bone by long boiling, till the elementary Earth is elixated, or drained of the other Principles; we hence learn, that the Matter of these other Principles proceeds only from the Juices of the Body; where, as well as in the Gelly, they appear in an almost insipid and inodorous State; tho' capable, by Distillation, of affording Substances so highly sapid and odorous, as we find the volatile Salt and Oil to be. Whence this Conclusion naturally follows, that these Principles did not exist in a volatile State in the Body; as requiring even a greater Degree of Heat, than that of boiling Water, to separate them.

34. We may farther observe, that the present Experiment affords us the most volatile Substance hitherto known: for well-purified animal Salt is more volatile than Spirit of Wine; and rises in Distillation before it. Hence this Salt readily evaporates in the open Air, and when laid upon the Palm of the Hand, goes off insensibly, without any Effect; tho' if it were pressed close to the Skin, by a sticking Plaister, it proves corrosive; and in this manner, it is sometimes used for making Issues in Children, instead of the stronger Caustick.

III.

EXPERIMENT III.

*at certain mineral or metallic Bodies may contain four of the chemical Principles, viz.* Sulphur, Salt, Earth *and* Mercury.

35. We took two Ounces of native Cinnabar, duced to fine Powder, and mixing it with six nces of Quick-lime; we put the whole into an thern Retort; and distilling into a Bason of ater, we found a considerable quantity of run- g Mercury at the bottom thereof*. The Mat- remaining behind in the Retort, being boiled *Lixivium* of Pot-ash, and the Solution precipi- ed with Allum; thus lets fall a fine kind of mstone, called *Lac Sulphuris*; which will lime into true Flowers of Brimstone, that y be melted, and run into a Roll. This Brim- ne being burnt, in the common Method, un- a Glass Bell, resolves into an acid Liquor, ving an uninflammable, scurfy, terrestrial tter behind; which being treated as an Ore, netimes affords a small Proportion of Metal, ner Iron or Copper. *Cinnabar analysed.*

36. We have here an instructive Experiment; ich being fully explained, might lead to con- rable Discoveries. It shews, that a true run- g Mercury may lie concealed in metallic es, or stony Earths; for native Cinnabar is an Ore of Mercury; consisting, as we see, two different Matters, Sulphur and Quick- silver;

* We endeavoured to separate the Sulphur from the Cin- r, by boiling some pulverized Cinnabar in a strong *Lixi- n* of Pot-ash and Quick-lime; expecting the Mercury d fall to the bottom in a running Form: but had no ess at the end of two or three Hours.

silver; which are separable by Distillation wit Quick-lime, or Iron Filings; and sometimes b long boiling in a strong alkaline *Lixivium*.

*The Experiment whether extendible.*

37. It were highly proper, if possible, render the present Experiment general; and, the Nature of the thing wou'd admit theree apply it to extract a running Mercury from M tals; as we have here done from a native Ore mineral Substance. For the more intellige Chemists agree, that the true Analysis of meta line Minerals depends upon what is called the *Mercurification*; that is, the obtaining Mercu from them. And for this purpose there a three Methods proposed. The first, by means a certain Mercury, so prepared as to have a d solving Power; and to take up the Mercur of Metals, in the same manner as Water dissolv Salt from Ashes. The second is by means certain regenerating Salts, particularly *Sal-A moniac*; which shall detain the more eart Parts of Metals, and leave their Mercuries sep rable from them by Sublimation or otherwi And the third Method is by means of a lar *Lens*, or double Convex Glass; in the Foc whereof, if any Metal be applied, its mercur Part is said to separate and go off in Fume, whi when collected and condensed, appears to running Mercury.

38. The first Method were easy, if the p per Mercury for the purpose cou'd be read procured. The second is extremely laborio and requires much Patience, and Reiterati But the third seems easy enough, and practica to advantage, when a Glass of three or four F in Diameter is at hand; the Sky serene, and Sun shines strong*.

39. I

* See M. *Homberg*'s Experiments, with the Duke of *leans*'s *Lens*; in the *French Memoirs*.

39. Let it not be miſapprehended, as if we were here launching out beyond the Confines of genuine Chemiſtry; whoſe Office it is to keep cloſe to the Senſes, without indulging any thing of Speculation and Hypotheſis: we only mean to give an Occaſion for the proper Trials to be made, which alone can determine whether running Mercuries are obtainable from Metals, or whether a fixed Metal may not be obtained from running Mercury. And we ſhou'd be wanting to the Art we endeavour to improve, if we did not, at a time when almoſt every Chemiſt in *England* is preparing the *Mercurius præcipitatus per ſe*, requeſt them to try whether a ſmall Portion of their fluid Mercury is not by the Operation fixed into a ſolid Grain of Metal; and if ſo, what Metal this is; and whether more of it be not procurable by grinding their Precipitate, and again expoſing it to Digeſtion; and repeating this Operation for a number of times ſucceſſively; till it may happen that part of it will bear the Cupel.

40. And in the ſame View, we recommend it to thoſe who deſire the Improvement of Chemiſtry, that they wou'd procure a double Convex-Glaſs, three or four feet in Diameter; and try if when a Metal is expoſed to the Focus thereof; the metallic Matter which goes off in Fumes, being collected by a proper Veſſel, and dextrouſly applied and plunged in cold Water; may not be thus condenſed, and aſſume the running Form and other Properties of an actual Quickſilver. If theſe Experiments ſucceed, they may richly repay the Coſt, by uſeful Knowledge at leaſt.

41. But to proceed; we are farther to obſerve from the foregoing Experiment, that as common Brimſtone reſolves itſelf into an acid Liquor, and an earthy Matter; we find that certain mineral

or metallic Subſtances, will, by a proper Analyſis, afford the four chemical Principles above mentioned; *viz.* running Mercury, Sulphur, Salt and Earth. But it is not ſuppoſed to hold univerſally, that all mineral Subſtances ſhou'd afford a running Mercury upon their Analyſis; but only ſuch of them as are properly metallic.

*Reſult of the Analyſis of Minerals.*

42. So far as the Analyſis of Minerals has been carried, it ſhou'd ſeem, that all Metals contain a running Mercury, fix'd in them, as Water is fixed in dry animal or vegetable Subſtances*; and joined with a Sulphur, or an inflammable Part, and an Earth; with a little Salt in ſome of them†. The Foſſil Salts reſolve into a large quantity of Acid, which is always united with ſome Sulphur; and a ſmall Proportion of Earth. Moſt Stones reſolve into a large Proportion of Earth, and a ſmall quantity of aqueous and ſulphureous Vapour. And Earths reſolve into a mere terreſtrial Subſtance, a little aqueous Acid, and a ſmall Proportion of Sulphur.

43. Upon the whole therefore we may conclude, that the five Principles above laid down, *viz.* Water, Earth, Salt, Sulphur, and perhaps Mercury, are the true Chemical Principles of vegetable, animal and mineral Subſtances‡.

## AXIOMS *and* CANONS.

1. It appears from our preceding Enquiry, That genuine Chemiſtry conſiſts in a legitimate Uſe of the Senſes; and keeping entirely to ſenſible

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* See *Lect* III. *ad finem*.

† See M. *Homberg* upon the Chemical Principles, in the *French Memoirs*.

‡ No Notice is here taken of Air as a Chemical Principle, for the Reaſon before aſſign'd. See above, § 3. See alſo *Lect* III. *paſſim*.

ble Things, or the Law of Induction for its Principles, and Explanations*; but, if it once indulges hypothetical Notions; Fiction, Illusion and Darkness ensue; instead of sure Rules, useful Discoveries and Light to the Understanding.

2. That the common chemical Principles are justly said to be Water, Earth, Salt, Sulphur and Mercury; whereby many chemical Effects are explicable to the common Sense and Reason; so far as to afford Rules of working to the advantage of the Art, and of ordinary Life†.

3. That as animal and vegetable Substances are resolvable into the same Principles‡, there is no necessity for making more than two Distinctions or Classes of chemical Principles, *viz.* the Vegetable and Mineral; which seem to differ chiefly in this, that the metallic Species of Minerals may afford a running Mercury; which the vegetable and simple mineral Species will not.

4. That the different Combinations of these five chemical Principles make all that vast variety of natural and artifical Bodies, which have hitherto been analysed by the Fire; the Difference of these Bodies appearing to arise from the different Proportions wherein these Principles are mixed. Whence, unless we except the Air, there seems no necessity for introducing a large Number of Principles to account chemically, for all the various Phænomena of Nature and Art.

5. That the correspondent animal and vegetable Principles may in many Cases be used for one another; so as to render volatile Salts and Oils cheaper; and lessen the expence attending their Use in particular Arts and Trades‖.



* See the whole Lecture, *passim*.
† See *Exp.* I, II.
‡ Ibid.
‖ Ibid.

6. That in order to leſſen the trouble and expence of procuring the volatile Salt of animal Subjects, theſe Subjects ſhou'd be firſt purged of their Oil, and unctuous Parts, by boiling in Water; after which, they may be made to afford volatile Salts and Spirits, as pure, or purer, than unboiled Hartſhorn *. But care muſt be taken not to boil the Subject too long, otherwiſe a Jelly will alſo be got out of it; which Jelly plentifully contains the Matter of the volatile Salt.

7. That the unrectified volatile Salts of vegetable and animal Subſtances, are true *Sales volatiles oleoſi*; according to the Difference of the Oil abounding, wherein they are properly diſtinguiſhed into Salt of Hartſhorn, Salt of Ox-bone, Salt of human Blood, Silk, *&c.* But that when theſe Oils are totally ſeparated from them, they become one and the ſame undiſtinguiſhable volatile Salt †.

8. That thoſe, called the *volatile Spirits* of vegetable and animal Subſtances are only a large Proportion of Water impregnated with ſome of the volatile Oil, and Salt of the Subjects; and accordingly that by Rectification, they may be reſolved into theſe three Principles; whence there is no neceſſity for introducing a ſpirituous Principle ‡.

9. That it is the admixture of Oil, which gives the Colour to volatile Salts, and volatile Spirits; for when this Oil is totally ſeparated from them, the Salt is permanently white, and the Spirit pellucid ‖.

10. Tha

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* See *Exp.* II.
† See *Exp.* I, II.
‡ Ibid.
‖ See *Exp.* II.

10. That volatile Salts are obtainable from all kinds of Land Animals, the amphibious and subterraneous Tribes, Birds, Fish, and Reptiles, from alkaline Vegetables without Putrefaction; from other Vegetables after Putrefaction, from Soot, Horns, Hoofs, and all refuse animal and vegetable Matters, such as the Pith of Horns, Urine, the Blood of Slaughter-houses, *&c.* and this as pure and perfect as from Hartshorn, which affords a Rule for the making volatile Alkalies and Sal-ammoniac cheap in *England*.

11. That elementary Earth, a Substance fixed, nd of itself unalterable in the Fire, Air and Wa-er, constitutes the firm Basis, or Skeleton, of all nimal and vegetable Substances; and that Wa-r, Salt and Oil mixed, and wedged betwixt the articles of this Earth, are what constitutes all nimal and vegetable Substances *.

12. That there is only one kind of volatile al-aline Salt; when reduced to absolute Purity: e apparent Difference betwixt the volatile Salts ntirely depending upon the different Oils where-ith they are mix'd †.

13. That by endeavouring to purify the che-ical Principles too high, we do but destroy eir Natures ‡; or lose the Properties whereby ey produce their specific Effects. Thus Oils, numerous repeated Distillations, are lost in the rm of Oils, and turn'd to Earths; volatile lts fly away in repeated Sublimations; and ed Salts turn to Earth by repeated Solution d Filtration ||.

14. That animal Bodies naturally contain no ed Salt, tho' the acid Vegetables, which are



* See *Exp.* I, II.
† See *Exp.* I, II. See also hereafter the Lecture upon *Oils*.
‡ See *Exp.* I, II.
|| See Mr. *Boyle's Sceptical Chemist*.

uſed as Food, contain it plentifully *. Whence there is lodged in the Body a Power of converting the Matter of fixed Salt into the Matter of volatile Salt.

15. That the volatile, animal and fixed vegetable Salts differ chiefly with regard to their Volatility and Fixedneſs, and the Effects thereon depending; but agree in other reſpects. Thus they both make an Effervescence, and turn neutral, when ſaturated with Acids; they are both corroſive, hot and fiery, *&c* †.

16. That a principal Reaſon of the Difficulties attending the Analyſis of Bodies, is the natural Affinity, or Relation, which ſome of the chemical Principles have to others: whence they cohere ſtrongly together, ſo as not to be well ſeparated pure ‡. Thus part of the volatile Oil of Animals uſually riſes with the ſame degree of Heat, as the volatile Salt; and intimately mixes therewith, *&c.* whence, to improve Chemiſtry, we ſhou'd ſeek out for other analyſing Powers, beſides Fire. And ſuch an one in the preſent Caſe is Water; which imbibing the volatile Salt, more ſtrongly than it does the Oil, thus makes a more perfect Separation; whereas, Fire acts as an Analyſer, chiefly when there is a conſiderable Difference between the Volatility of Bodies, as in a Mixture of Water, Alcohol, and volatile Salt; all which riſe ſeparately after one another, the volatile Salt firſt, the Alcohol next, and the Water laſt.

17. That the Mercuries of Metals may be real things, and procurable different Ways; and that poſſibly theſe Mercuries, or the common running Mercury, may be convertible into Metal.

* See *Exp.* I, II.
† Ibid.
‡ See *Exp.* I, II, III.

tal. But this Matter requires a farther Examination, and ſhou'd be brought under the direct Evidence of Senſe *.

18. Laſtly, that there are certain Inſtruments and chemical Operations, little attended to, which may afford great Light to the Underſtanding, and prove highly advantageous in chemical Philoſophy and Arts; we inſtance, for the preſent, the Mercurification of Metals, the powerful Furnace of the Sun, the artificial Uſe of the common Elements, *&c* †. all which we recommend to the farther conſideration of chemical Philoſophers.

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* See *Exp.* III.

† Ibid.

# LECTURE IX.

## CONTAINING,

## Synthetical Chemiſtry; *or, the Art of Recompoſing Bodies.*

*The Subject.*

1. IN our laſt Lecture we endeavoured to explain what the more intelligent Chemiſts underſtand by *analytical Chemiſtry*, or the Reſolution of Bodies; in the preſent, we propoſe to give ſome Inſtances of Recompoſition, or the compounding of Bodies from their ſeparated Parts, or Principles: ſo as to compoſe the Original whole again. This indeed is extremely difficult to effect univerſally; yet it may be done in ſome caſes; ſo as that the recompoſed Body ſhall be perfectly undiſtinguiſhable, by the Senſes, from that which had never been ſeparated by the Fire. And if the Art of Chemiſtry were perfect; it wou'd be able thus to recompoſe, at leaſt in ſome tolerable manner, all the Bodies it divides. At preſent it is far from this Perfection; eſpecially in the vegetable and animal Kingdoms; where, by reaſon of the vaſcular Texture of the Parts, ſuch a Recompoſition ſeems almoſt impracticable; unleſs the natural or organical Structure be ſome way or other preſerved, or artificially imitated: whence we are carefully to diſtinguiſh betwixt the Regeneration of organized, and the Regeneration of unorganized Bodies. And as the latter is much the more ſimple, and eaſy, we ſhall begin with that; aſcending by degrees to the more complex kinds; ſo as to ſhew where this

this Regeneration may be rationally expected; and where it is leſs to be hoped for; with the ways of carrying this Part of Chemiſtry to greater Perfection.

2. This *Synthetical Chemiſtry*, taken in the ſtrict Senſe, for the Recompoſition of Bodies from their own Principles, is rather of philoſophical than ordinary Uſe. And it will doubtleſs be asked, to what purpoſe do we ſtudiouſly endeavour to recover thoſe Bodies by Art, which Nature affords us in plenty? We anſwer, it wou'd ſhew an extreme Perfection and Power of Chemiſtry, to be able to do this; and prove, either that Bodies might be taken to pieces by the Fire, without altering or injuring their natural Parts; or at leaſt that any accidental Alteration brought upon them by the Analyſis, might eaſily be rectified or aboliſh'd by a Recompoſition. *Synthetical Chemiſtry.*

3. But here we are to guard againſt a Fallacy; for ſuppoſing the Art of Chemiſtry ſo far advanced, as to reinſtate Bodies after their Analyſis; we muſt not thence conclude that Nature originally uſes the ſame Means to compoſe them. The Ways ſhe uſes for this purpoſe, wou'd ſtill be a new Enquiry; and ought to be diligently proſecuted, for the farther Improvement of *Philoſophical Chemiſtry.*

4. Our firſt Example of Recompoſition is taken from Nitre; the ſecond from Brandy; the third from Cinnabar; and the laſt from Bone.

## Experiment I.

*The Regeneration, or Recompoſition of Nitre; from its own acid Spirit, and fixed Alkali.*

5. We took two Pounds of refined Salt-Petre, reduced to Powder; and putting it into a Glaſs-Retort, *Nitre analyſed; or reduced to a Spirit.*

Retort, we poured upon it a third of its own Weight of rectified Oil of Vitriol; then placing the Retort in a Sand-heat, and luting on a large Receiver, we distilled with degrees of Fire, up to the highest that Sand wou'd give. Then suffering all to cool, we thus obtain'd a pure and strong *Spirit of Nitre*; which came over in red Fumes, and cannot, by any Experiment, be found to participate of the Oil of Vitriol, used in its Preparation.

*And a fixed Salt.*

6. On the other hand, we took a Pound of purified Nitre, reduced to Powder; and melting it in an earthen Crucible, throw'd little pieces of Charcoal into it successively, till the Sublimation ceased; and the Salt, at the bottom of the Crucible appear'd sluggish, or wou'd no longer keep fluid with that degree of Heat which melted it before. Then increasing the Fire, so as to make the Salt run again, we poured it out upon a clean metalline Plate; where it congeal'd into a Substance, called *fixed Nitre*.

7. And thus, at two different Operations, we resolved the same Subject, Nitre, into two very different Parts; which being put together again after a proper Manner, constitute the original Salt again, in all its Forms.

*Recomposed.*

8. For if the alkaline Solution of fixed Nitre in Water, be exactly saturated with the acid Spirit of Nitre, till no more Effervescence appears; and yet the Mixture be not made alkaline; this compound Liquor will, by standing, shoot into true and perfect Crystals of Nitre; as we found upon Trial. And the Experiment succeeds no less, if any other fixed alkaline Salt, as that of Nitre, Pot-ash, *&c.* be used instead of fixed Nitre.

9. And in the same manner may common Salt be regenerated from any fixed alkaline Salt

and

and the acid Spirit of Sea-Salt; or Alum, from any fixed alkaline Salt and Spirit of Alum; so as to afford us Instances of perhaps the justest Recomposition hitherto known in Chemistry.

10. It is remarkable in this Experiment, that the two Substances which compose the Nitre, are extremely different; the one being highly odorous and volatile; the other inodorous and fixed; the one a violent Acid, the other a violent Alkali; but upon mixing, they unite into a neutral Salt, of the very same Nature and Properties with that which afforded them. *Uses.*

11. From this Experiment some have ventured to affirm that Nitre is naturally generated in the same manner; but this shou'd not be allow'd till it is shewn that such an Acid and such an Alkali are to be found distinct in the places where Nitre grows. And we cannot too well remember, that there may be several physical Ways of effecting the same thing; all which Ways are not to be presumed, but sought.

12. To this Class of artificial Recompositions, may be added the Reproduction of Sulphurs and Vitriols; tho' the Experiments do not commonly succeed in Perfection. And as we above observed, the Thing itself having chiefly a philosophical Use, only a very few Persons have endeavoured to improve it.

13. In our present Experiment we may observe, that the Nitre, tho' in both Cases it suffers a great Violence of Fire, yet is not scorched or render'd empyreumatical; which in other Cases, where the Subject is more oily, seems a principal Cause of the Difficulties found in the regeneration of Bodies; particularly such as Sugar, Turpentine, Amber, *&c.* whence we are directed to analyse these unctuous Bodies with such a degree of Heat, as shall not scorch their Oil; if we desire

fire to recompose them; or else to find o some more proper Analyser for them than t Fire; such as particular Solvents, capable of s parating, and others of reuniting their compo nent Parts; without having this destructiv Effect.

14. The Solvents here intimated, might hav considerable Uses, if a competent Set of ther were discover'd; and as directly tending to th Improvement, both of *analytical* and *synthetic Chemistry*. Thus Water in some Cases is a bette Analyser than the Fire; as we see particularly i the separating of Salts from Earths; and thu some Chemists are said to have a Method of re covering analysed Amber, or Amber distilled for its Salt and Oil; by means, not of the Fire, but of an artificial compound Salt. The In stances of which kind shou'd be collected.

## EXPERIMENT II.

*Brandy resolved into its component Parts, and recomposed.*

*Brandy analysed.*

15. (1.) To a Pint of Brandy we added half a Pound of dry Salt of Tartar; then set the containing Glass in a gentle Heat of Sand; where we observed the Salt to dissolve into a Liquor, by attracting to itself the Water of the Brandy; leaving a Spirit of Wine floating on the top. This Spirit we decanted upon a little more dry Salt of Tartar, and found that this second Salt scarce relented. Then pouring the Spirit into a Glass Receiver, we distill'd it gently over, and thus obtained a highly rectified Spirit of Wine. (2.) In the same manner we distill'd the saline Solution, left behind upon decanting the Spirit; and thus obtain'd the Water of the Brandy in considerable Purity, leaving the Salt of Tartar,

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in a dry Form, behind. (3.) In the laſt place, we mixed the Spirit and the Water together; and directly found the Brandy recompoſed; without any conſiderable Alteration. *And recompoſed.*

16. The Separation and Recompoſition is however leſs exact in the preſent, than in the preceding Caſe; becauſe ſome ſmall part of the Salt will always come over in Diſtillation, both along with the Spirit and the Water: but when the Experiment is perform'd in perfection, it may paſs for a tolerably exact Recompoſition.

17. To this Claſs may be added the Recompoſition of Wine, after its Spirit or Brandy has been diſtilled from it; and the Recompoſition of Vinegar from its Spirit and *Reſiduum*; both by means of a new Fret; or a ſlight Fermentation. And if the Operation in theſe Caſes be dextrouſly performed, the Recompoſition appears to be juſt and perfect. To perform the Operation perfect in either Caſe, we recommend the Uſe of a proper intermediate Subſtance; which is either fermentable, or actually in a fermenting State: ſuch as a little new Wine, Sugar, Juice of the Grape, or the like; for theſe Subſtances thus coming to work in the Liquor, lay hold both of their aqueous, and ſpirituous and ſaline Parts; ſo as to bring them into the State of Mixture or Arrangement, whereon their Perfection, as Wines, and Vinegars, depends. And how far this Method of Recompoſition may be extended, ſeems hitherto little conſider'd. *The Experiment extended.*

18. In our preſent Experiment for the Recompoſition of Brandy, there are only two conſtituent Parts concerned, *viz.* Alcohol and Phlegm; which renders the Separation and Combination ſo much the eaſier, and more exact; nor is there any occaſion here for an intermediate Subſtance,

to

to procure, or recover the natural Union; becauſe Alcohol readily mixes with Water, barely by ſhaking; and this as intimately as is neceſſary to the Conſtitution of Brandy.

19. In imitation of this Experiment, it is proper to enquire what other Bodies there are which may be perfectly ſeparated into different Parts by the way of Menſtruum, Abſorbent, or Precipitant; ſo as to leave the ſeparated Matters unalter'd in their Natures; and fit to compoſe the original Subſtance again. This Enquiry depends upon finding out the ſecret Relations which exiſt betwixt particular Bodies; and theſe Relations can only be diſcover'd by particular Trials*.

*Farther Uſes.*

20. This Experiment ſhews an uſeful Method of obtaining Spirit of Wine from Brandy, without Diſtillation; and may be practiſed to advantage, in the large way of Buſineſs; by adding Pot-aſh to the Brandy once diſtilled, and brought to a Size, commonly called *three Fifths*, that is, three parts Alcohol and two of Water: For the Pot-aſh ſo employ'd, is eaſily recoverable without much loſs; barely by boiling the Lixivium, in an Iron Pot; where being made dry, it will ſerve for the ſame purpoſe again. This ſlight Experiment has proved of eminent ſervice, where large Parcels of Brandies have been to be rectified in a ſmall Compaſs of Time.

## EXPERIMENT III.

### *Cinnabar recompoſed, by the Union of its two component Parts,* Sulphur *and* Mercury.

*Cinnabar recompoſed.*

21. Having found, in our laſt Lecture, that native Cinnabar is compoſed of Sulphur and Mercury †; we now took four Ounces of common

* See M. *Geoffroy*'s Paper to this purpoſe in the *French Memoirs.*

† See *Lect.* VIII. *Exp.* III.

mon Brimſtone; and melting it in an earthen Pan, over a dull Fire; added by degrees, twelve Ounces of crude Quickſilver, firſt made warm, and ſtirring them well together, till no Globules of the Quickſilver appeared: Then ſuffering the Maſs to cool, we reduced it to Powder; and ſublimed it, with a proper degree of Heat; and thus obtained, an artificial Cinnabar; which being ground fine, and compared with the natural, appeared undiſtinguiſhable from it.

22. The regenerated or artificial Cinnabar has not the ſtony Form of the native; this Form being accidental in the Mine; and determined by the Circumſtances of the Place, as the Form of the regenerated Cinnabar is by the Figure and Make of the Veſſel wherein it was ſublimed. And if the two be compared together, in all other reſpects, there appears no difference; when the Operation is juſtly performed. *Uſes.*

23. This Experiment ſhews us the common Method of preparing artificial Cinnabar, which may, in the large way of Buſineſs be thus ſublimed in a tall earthen, or (with its Head well luted on) coated Body; and ſo placed in a Sand-Heat, as to touch the Bottom of the Iron-Pot; whilſt the Sand riſes above the Matter contained in the Veſſel. And here it is a principal Caution to uſe a brisk Fire, that the Operation may be finiſhed in three or four Hours time. And perhaps, if only one part of Sulphur be uſed to about four parts of Quickſilver, the Cinnabar will be the finer: for about thirteen Ounces of running Mercury may be recover'd from a Pound of native Cinnabar.

24. And thus we have an Inſtance of a perfect Decompoſition, in a metallic Body, or Subject of the mineral Kingdom: for the Experiment ſucceeds alike, when the Sulphur and Mercury

of

of native Cinnabar is uſed*. And to this Claſs might be referred the Reduction, or Recovery, of all the Calces of Metals, to a metallic Form again; by the addition of any inflammable Matter, which they loſe in their Calcination: as alſo the Regeneration of Antimony, by melting its Regulus with Sulphur; the Regeneration of Ores, by melting their Metals with Sulphur, ſtony Earths, &c. ſo as not to mix them again; and all other Inſtances of this kind.

25. The preſent Experiment is of conſiderable uſe; particularly in natural Philoſophy, and Metallurgy: as it ſhews us that a very large Proportion of fluid Mercury may, by means of a very ſmall one of Sulphur, be fixed into a Body, of a ſtony Hardneſs; ſuch as the native Cinnabar. Whence we ſhou'd not be over-haſty to conclude, that Mercury cannot aſſume a metalline Form†. Some metallurgical Chemiſts contend, that Mercury is nothing elſe but a Metal, overdoſed with that Part which gives ductility and ſoftneſs; as all the Metals remarkably appear to be, when amalgamated with Mercury. And whoever duly lays together all the Properties of Mercury, may perhaps find cauſe to allow it of a metallic Nature‡.

## EXPERIMENT IV.

### *An Attempt to recompoſe Bone, from its Aſhes.*

*Bone recompoſed.*

26. (1.) We took a large Ox-Bone, and made a ſtrong Jelly thereof, with Water in the Digeſtor‖: then (2.) in an open Fire, burnt and calcined the Bone to whiteneſs, without deſtroying it

* See *Lect.* VIII. *Exp.* III.
† Ibid.
‡ See the place laſt quoted.
‖ See *Lect.* VI. *Exp.* VII.

its external Figure; ſo that in other reſpects the Bone was reduced to mere Aſhes, or ſeparated from the Principles of Water, Oil, and Salt; which it originally contained. In this ſtate we found it extremely brittle and crumbly; but (3.) putting it into the Digeſtor again, to the Gelly, and warming them together over the Fire for ſome time; then taking the Bone out, and ſuffering it to dry in the open Air, we found that it gradually harden'd, and recover'd, in ſome tolerable degree, the Appearance, or Colour and Conſiſtence, of the natural Bone.

27. Gelly, by an Analyſis, is found to yield the ſame Principles as Bone itſelf*; or to contain the matter, not only of Water, but of Salt and Oil, and a little Earth: ſo that to uſe this Gelly, is the ſame thing as to uſe the Water; all which being thus together ſoaked into the Skeleton of the Bone, reſtores it in ſome degree to its natural State.

28. But to have uſed the direct volatile Salt and Oil of the Bone, for this purpoſe, were to uſe two things which did not exiſt in thoſe forms in the Bone; for to ſeparate the volatile Salt and Oil from Bone, requires a much greater degree of Heat than that natural to an animal Body; whence they are never thus ſeparated in the Body, whilſt that remains in its natural ſtate. Tho' a Degree of Hardneſs (with Diſcoloration, on account of the black and ſcorched Oil of the Subject) may be given to Bone-Aſhes, by the ſeparated Oil, or even by Water, as we ſee in Teſts.

29. We were farther encouraged to uſe the Gelly of the Bone in this Experiment, from obſerving that, by repeated Operations in the Digeſtor†, all the active Principles of the Bone



* See *Lect.* VIII. *Exp.* II.

† See *Lect.* VI. *Exp.* VII.

might be got out and united with the Water, added to extract them; so as to leave nothing but a little Earth behind; resembling the Ashes left upon a dry Calcination in a violent Fire. Whence we are plainly instructed in the nature of animal Gelly; with its Uses to the Body. And hence also we learn the Nature of Mucilages, Size, Glues, and may understand many things relating to Medicine, the animal Oeconomy and Arts.

*Uses.* 30. This Experiment might be render'd more successful, if we cou'd procure the tenacious Glue or Cement, which obstinately remains in the Pores of the Bone, even tho' long detain'd in the Fire. This Glue seems to be an intermediate Substance of a middle nature, betwixt Gelly and elementary Earth, whence it were proper to try, if by grinding the elementary Earth fine, and digesting it with Gelly; some such tenacious Glue could not be procured. This also might open the way to a History of Glues, which is extremely wanted in Chemistry, natural Philosophy, and Arts.

31. If a promiscuous Mass of elementary Earth be used, instead of that which retains its natural vascular Form; a kind of Callus would be thus produced, instead of a regular Bone. Whence we may be enabled to judge of the Nature and Formation of the *Callus*, formed in the Bones of Animals.

32. After the manner of our present Experiment, we might also attempt to recompose vegetable Subjects. But before any thing of this kind is done to perfection, Chemistry will require the Assistance of mechanical Contrivance; and many Improvements from the Anatomy of Plants; particularly it must learn to preserve the native Spirits of Vegetables, upon their Analysis; or else the artificial ways of imitating and introducing

ducing such Spirits into the Subject. These Spirits are extremely apt to fly off with Heat; but may in good measure be collected and preserved by Art. And unless they are thus preserved, the Subjects will want their native Tastes and Odours, which depend upon these Spirits, or subtile, volatile Matters.

33. The highest Degree of Recomposition, is, when a Body is perfectly resolved into its Principles; suppose a vegetable Subject into Water, Salt, Oil, and Earth; and these be again put together, so as to form a Subject undistinguishable from the Original. In order to attain to this Perfection, let the thing be first tried in similar, unorganized Bodies; as Glass, Turpentine, Amber, Vegetable Juices, Wines, Sulphurs, Ores, *&c.* proceeding by slow Degrees, up to the more dissimilar and organical Bodies; such as vegetable and animal Subjects. *Perfect Recomposition.*

34. We have seen that, in many Cases, a true Resolution and Recomposition are practicable; and as Chemistry improves, the Business of *Analysis* and *Synthesis* must likewise improve.

35. But let it be observed, that the Power of Chemistry is not limited to the Business of just Resolutions and Recompositions; it can produce numberless Effects without going to this Exactness. Thus it already analyses and recomposes, or separates and mixes, all the natural and artificial Bodies, in its own imperfect manner. And thus it has furnished us with all Chemical Medicines; as Tinctures, Extracts, Spirits, Oils, Waters, Essences, *&c.* and the several Commodities of Sugar, Wine, Alum, Salt, Pot-Ash, Aqua-Fortis, Oil of Vitriol, Soap, Glass, *&c. &c. &c.* For without attempting a perfect Separation, or Recomposition of the chemical Principles, a gross Separation or Mixture of two or *The Imperfect useful.*

three of them will frequently afford very uſeful Subſtances; ſo that Chemiſtry, tho' it remains imperfect, is ſtill highly ſerviceable.

## AXIOMS *and* CANONS.

1. We learn from the preceding Enquiry, that we cannot ſafely conclude Bodies to have been originally compoſed of the ſame Principles, into which the Fire reſolves them *.

2. That, as the Fire, in many Caſes, proves a juſt Analyſer; and reſolves Bodies into their conſtituent Parts, without Alteration; ſo, in others, it quite perverts and changes their Nature and Properties; eſpecially by ſcorching the Oil of the Subject, when the Subject abounds with Oil †.

3. That the perfect Regeneration of Bodies can only take place in ſuch Caſes, where the Fire, or other Inſtrument, is a true Analyſer; without adding any extraneous thing of its own; or any way altering or ſubverting the nature of the Parts ſeparated ‡.

4. That the Buſineſs of Recompoſition is to be diſtinguiſhed into three kinds, *viz.* mineral, vegetable, and animal, differing in Degree of Facility; the mineral kind being the eaſieſt; and therefore to be firſt cultivated, in order to improve Synthetical Chemiſtry, and render it more advantageouſly practicable in organical Bodies ‖.

5. That *Synthetical Chemiſtry* is more imperfect than the *Analytical*; or that the preſent Chemiſtry divides natural Bodies more perfectly than it puts them together again, for want of more proper

Ana-

* See §. III. *Exp.* I.
† See *Exp.* I. See alſo *Lect.* VIII. *Exp.* II.
‡ See *Exp.* I, II, III, IV.
‖ See *Exp.* I, III, IV.

Analyſers than Fire; and more ſuitable Methods and Menſtruums than are hitherto diſcover'd *.

6. That a new Compoſition is uſually made in every chemical Reſolution. Thus when Nitre is ſeparated into an acid Spirit, its fixed Salt remains compounded with the Oil of Vitriol †. When Mercury is ſeparated from the Sulphur in Cinnabar, the Sulphur remains united with the Quick-Lime, or Iron-Filings ‡. When Water is ſeparated from Brandy, the Water unites with the fixed Salt; and leaves the Spirit to float ſeparate ‖. And this appears to be generally the Caſe; ſo that the Separation is made by ſome intermediate Body, which unites with one part, and not with the other of the Subject **. Whence we are directed to find out the *Mediums of Mixture* and *Recompoſition*, as well as of Separation, in order to perfect *Analytical* and *Synthetical Chemiſtry*.

7. That Bodies endowed with a native Spirit, are hard to recompoſe, unleſs this Spirit be ſome way artificially preſerved ††. Thus for inſtance, Seeds, Roots, Flowers, *&c.* may be dried in cloſe Glaſſes, with blind Heads, ſet upon a gentle Sand-Heat; then taking the Subject out, and ſeparating its Principles, the Oils and Salts being afterwards impregnated with the native Spirit of the Subject, remaining in the Blind-Heads; ſo as thus to recompoſe the whole in ſome tolerable Degree.

8. That animal Gelly is a Mixture of all the Principles of an animal Subject, *viz.* much Water,



* See the preceding Lecture, *paſſim*.
† See *Exp.* I.
‡ See *Lect.* VIII. *Exp.* III.
‖ See *Exp.* II.
** See *Exp.* I, II, III, IV.
†† See § 31, *&c.*

a moderate Proportion of Oil and Salt, and a little Earth *. Whence they learn the physical Cause, why Gelly is nutrimental; why animal Substances so much abound therewith; its Uses in the Body; its restorative Nature, &c. And hence we have a Foundation for the natural and experimental History of Gellies, Size, Glues, &c †.

9. That the Business of Analytical Chemistry is deficient, which ought to afford the Rule of operating to Synthetical Chemistry ‡. Thus most of the Analytical Operations hitherto performed, are but superficial Attempts to enter and open the Substances of natural Bodies; for which purpose, in some Cases, long Digestions, repeated Reverberations, vaporous Mixture, exquisite Triture, continued Fusion, subtile Precipitations, &c. are required. Whence the Improvement of Synthetical Chemistry will greatly depend upon the Improvement of the Analytical.

10. That another way of improving *Synthetical Chemistry* is carefully to observe what Steps Nature takes in supplying and re-uniting the Bodies of vegetable, animal, and mineral Substances; and whether there be any real Instances of Regeneration in Nature, from the direct Principles themselves, without Addition; or whether this Action is not usually performed by some certain Assistance within the power of Art to procure; and particularly what is the Office of the Air, Water, and Fire, in bringing about this natural Operation ‖, in the way of *Fermentation*, *Putrefaction*, *Accretion*, *Nutrition*, and the general Principles of Motion or Life **; and whether th

* See *Exp.* IV. See also *Lect.* VI. *Exp.* VII.
† See above §. 28. See also *Lect* VI. *Exp.* VII.
‡ See *Lect.* VIII. and the present *passim*.
‖ See *Exp.* I.
** See *Lect.* VII. *passim*.

the common Elements do not contribute some part of their Substance, as well as Energy, in the Change *. And from such an Enquiry, conducted in the regular manner, it should seem that some capital *Canons* might be derived for improving this grand part of operative Philosophy.

* See the preceding Lectures upon the Elements.

# LECTURE X.

## CONTAINING,

*The Curation of Vegetables, or the Means of preparing and fitting vegetable Subjects for various Uſes, viz.* Brewing, Diſtilling, Vinegar-making, &c.

*The Subjects.*

1. WE are now proceeding to examine into the Nature of Seminal Vegetation, and the Curation or Preſervation of Vegetables, with a View to the Improvement of Chemiſtry, and the Arts thereon depending.

*Its Extent.*

2. The Subject is of large Extent, and if duly proſecuted, might tend to the Enrichment of the preſent Arts; or the Diſcovery of new ones. For on regulating the Growth, and curing of Vegetable Productions, depends the Perfection of Corn, Wines, Malt, Bread, Sugar, Tobacco, Spice, Drugs, Simples, Dying-Stuffs, and the like. And new Diſcoveries either in Vegetation, or Curation, might eaſily introduce new Trades; as has been the Caſe in Sugar, Tobacco, Wines, Spirits, &c.

*The Proceedure.*

3. By Experiments in Vegetation, we here propoſe to ſhew the Methods of regulating or conducting this natural Power for the Service of Arts; by directing it to anſwer particular Ends. Thus by ſtopping ſhort towards the beginning of Vegetation in Barley, we procure Malt; and by permitting the Grapes to hang 'till they grow not only ripe, but almoſt dry, upon the Vine, we procure rich ſweet Wines. And thus we

may

may ſtop Vegetation at any Period, or continue it longer than ordinary, according as the Occaſions of different Arts require.

4. By Experiments in *Curation* we wou'd ſhew the Methods of collecting, preparing, and ſecuring vegetable Commodities; ſo as that they may long remain ſound, perfect, and fit for Service. And thus our preſent Lecture will conſiſt of two Parts; the one relating to the ways of *growing* Vegetables, according to the Uſes for which they are intended; and the other to the *gathering* and *preſerving* them, ſo as to have them conſtantly ready at hand, when they come to be required in uſe. *Curation what.*

5. Our firſt Experiment therefore is calculated to ſhew the Method of ſtopping the natural Proceſs of Vegetation in the Seed; ſo as to prepare Grain, Pulſe, Nuts, Maſt, and Roots, for the making of Beer, Vinegar, and Spirits. Our ſecond is deſigned to ſhew the Method of curing both fermented and unfermented vegetable Juices, ſo as to make them keep ſound and good for ſeveral Years. Our third Experiment tends to ſhew the Method of curing vegetable Juices by Decoction, or Inſpiſſation, for the Service of Brewing and Diſtilling. And our fourth and laſt Experiment will ſhew the Method of curing Yeaſt, the Flowers of Wine, and Wine-Lees, for the Service of ſeveral Arts. Theſe Experiments now follow in order. *The Deſign of the Experiments.*

## Experiment I.

*The Method of ſtopping the natural Proceſs of Vegetation, with a view to Malting; or the Preparation of Grain, Seeds, Pulſe, Nuts, Maſt and Roots, for the making of Beers, Vinegars, and Spirits.*

6.

*Malting.* 6. We plucked up a parcel of Garden-Beans, after they had been ſuffer'd to lie in the Ground about ſix Weeks in the Winter-Seaſon; and found each Bean beginning to ſplit, or ſeparate, into its two *Lobes*; whilſt the *Radicle* was ſhot out ſome Inches downwards, and had begun to take Root in the Ground; the *Plume* alſo, which becomes the Stalk of the Bean, being riſen to the height of two Inches. In this ſtate we dried a few of theſe over a clear Fire, and thus found them turn'd to a kind of Bean-Malt, that taſted ſweetiſh, bit mealy betwixt the Teeth, and diſſolv'd freely in warm Water; ſo as to afford a Wort, fit for fermenting, with Yeaſt, into a kind of Beer or Ale.

7. This Experiment inſtructs us in the ordinary Proceſs of Malting; which, in the Caſe of Barley, is conformable hereto: and in the caſe of Malting *Indian Corn*, is the Proceſs itſelf *.

*The Proceſs of Malting.* 8. In making Malt from Barley, the uſual Method is to ſteep the Grain, in a ſufficient quantity of Water, for two or three Days, 'till it ſwells, becomes plump, ſomewhat tender, and tinges the Water of a bright brown, or reddiſh Colour. Then this Water being drained away, the Barley is removed from the ſteeping Ciſtern, to a Floor, where it is thrown into what they call the *Wet-Couch*; that is, an even heap, riſing to the height of about two foot. In this *Wet-Couch* the capital part of the Operation is performed; for here the Barley ſpontaneouſly heats, and begins to grow, exactly in the ſame manner as in our preſent Example of Beans; ſhooting out firſt the *Radicle*, and if ſuffer'd to continue, then the *Plume*, *Spire*, or *Blade*. But the Proceſs is to be ſtopp'd ſhort at the Eruption of the Radicle; otherwiſe

* See below §. 10. See alſo ſome Experiments to this purpoſe in the *Philoſophical Tranſactions*.

otherwiſe the Malt would be ſpoiled. The way to ſtop it, is to ſpread this Wet-Couch thin over a large Floor, and keep it turning once in four or five Hours, for the ſpace of two Days, laying it ſomewhat thicker each time. After this, the Malt is again thrown in a large Heap, and there ſuffer'd to grow ſenſibly hot to the hand, as it uſually will in twenty or thirty Hours time; then being ſpread abroad again, and cooled, it is thrown upon the Kiln, to be dried criſp, without ſcorching.

9. And this is the general Proceſs of Malting, wherein almoſt every Malſter has his ſecret or particular way of working. But to render the Operation perfect, the following Cautions muſt be obſerved: (1.) That the Barley be newly thraſhed, or at leaſt newly winnowed. (2.) That it be not mixed or made up of different Sorts. (3.) That it be not over-ſteeped in the Ciſtern, or ſo long as to make it ſoft. (4.) That it be well drained. (5.) That it be carefully looked after in the Wet-Couch, ſo as to ſtop the firſt Tendency of the Blade to ſhooting. (6.) Another Caution is, to turn the Wet-Couch inſide outermoſt, if the Barley *comes*, that is, ſhoots more in the middle than on the ſides. (7.) To keep it duly turning after it is out of the Wet-Couch. (8.) To give it the proper heating in the dry Heap. (9.) To dry and criſp it throughly upon the Kiln, but without a fierce Fire; ſo as to be ſeveral Days in drying a Kiln of Pale Malt. And if theſe Directions be carefully obſerved, the Malt will always be good.

*How managed to beſt advantage.*

10. The Method of Malting *Indian Corn*, or *Virginia Wheat*, is much leſs laborious. For if this Corn be buried two or three Inches deep in the Earth, and covered with the looſe Mould, dug up to make room for it; in ten or twelve Days time the Corn will ſprout, and appear like

a green Field; at which time being taken up, and washed or fanned from its Dirt, it is immediately committed to the Kiln, and by this means it becomes good Malt, exactly as Beans, so treated, would do.

11. It is observable of this Corn, that both its Root and Blade must shoot to a considerable length, before it will make Malt. And perhaps this is the Case in all large-bodied Grain and Nuts*.

*Extended.* 12. It might be of service to transfer this easy Experiment to the making of Malt from Barley, Rice, and the other small Grains and Seeds; but the Attempt may be attended with Difficulties; because in the making of Malt, the Barley must only be suffer'd to grow in its Root, and not in the Blade; whence it would be difficult, at first, to hit the exact time for taking it out of the Ground. And, again, as the Grain is so small, it might prove troublesome to separate it from the Earth or Mould. However, the thing may deserve to be tried †.

*Its Effects, and End.* 13. It is a Consideration of a higher nature to determine the physical Effect procured by Malting; and whether the End may not be obtained by cheaper and less laborious means. The physical difference betwixt malted and unmalted Corn appears to be the Production, or Extrication, of a sweet saccharine Substance in the Malt, which is wanting under that form in the Corn. And it is this sweet Substance alone, which we require in

* It may be worth trying, whether the same Process is not, with due Care, applicable to the Malting of Turnips, Potatoes, Carrots, Parsnips, &c.

† And possibly some Contrivance might be found, by the means of large Hair-Cloths, or otherwise, to inclose the Grain, so that the loose Earth should not mix among it; and at the same time an opportunity be afforded, of commodiously examining how far the Barley is *come* at any time after lying.

in Malt, for the making of Beer, Ale, Vinegar, and inflammable Spirits*. But even unmalted Corn, duly treated, may be made to afford Beer, Ale, Vinegar, and Spirits; this, therefore, may intimate to us a way of making ſuch Liquors, without the formal Extrication of any remarkably ſweet ſaccharine Subſtance. And according to ſome Trials we have made, unmalted Corn affords half the quantity of inflammable Spirit by Fermentation and Diſtillation; as the ſame Corn would do when malted. And ſuppoſe that unmalted Corn were to be made into a kind of Dough, or Paſte, fermented with Yeaſt, as is uſual for Bread, and then baked; wou'd not this be a cheap Subſtitute for Malting†? At leaſt, it deſerves to be tried, how much Beer, Ale, Vinegar, and Spirit, might be procured this way, compared with that other of Malting.

14. On the other hand, if only a ſweet ſaccharine Subſtance be required in Malt, are there not cheaper and eaſier ways of procuring it than by Malting? Do not many Trees afford ſuch a ſaccharine Juice, by Tapping in the Spring, without prejudicing the Trees? Is not young green Corn itſelf remarkably ſweet; and does not this ſweet Juice enter the Compoſition of the Ear, and there remain fixed, or almoſt loſt in a ſaccharine Form, 'till recover'd by Malting? Here is a Door open'd for explaining the Nature of Sweetneſs, and deducing the particular Hiſtory of Sugar; which is a Work, that, for its Uſefulneſs in Trades, and ordinary Life, we wiſh were extant. And 'till ſome conſiderable Progreſs is made in a Work of this kind, the Art of Malting, and

* See *Lect.* VII. *Exp.* I, II, IV.

† They are ſaid to brew after this manner in ſome Countries.

and all thoſe that depend upon it, will not arrive at perfection.

15. Thoſe, who are diſpoſed to go upon the Enquiry, may pleaſe to compare the Art of Starch-making with that of Malting; and particularly try whether ſome conſiderable Uſes might not be made of the *Refuſe Liquors* produced in both Arts. The high-coloured Liquor drained away from the Barley in the ſteeping Ciſtern is a vegetable Tincture, that might, if not by itſelf, yet by being uſed inſtead of Water to ground Malt, be worth fermenting and diſtilling for Spirit: and the Starch-makers refuſe Liquors have been obſerved to contain a quantity of inflammable Spirit.

16. Our preſent Experiment may in this reſpect be made general, that it ſhews us there are different times of ſtopping, or preventing, the farther Growth of Vegetables, for the Service of Arts. And this Doctrine may be extended to the forming a Set of general Rules, for gathering the different Parts of Plants, at different Seaſons of the Year, for different Uſes.

*Uſes.* 17. Thus Roots, for inſtance, to be had perfect, ſhou'd be gather'd and dry'd in the Spring before the Leaves are formed; Leaves ſhould be gather'd when they are fully open'd, but before the Flowers appear; Flowers when they are not fully open'd; and ſome, as red Roſes, in the Bud. Seeds are to be gather'd when full ripe, and beginning to dry, before they fall ſpontaneouſly. and Trees are generally beſt fell'd and ſtaw'd for their Bark in the Beginning of the Spring. But all this is to be underſtood of the common Uſes of the Subjects; for there are many particular Occaſions, which require them immature. Thus Buckthorn-Berries ſhou'd be ripe gather'd, for

making

making the Syrup; but unripe, for making the Painter's Colour called *Sap-Green*.

## Experiment II.

### *A Method of curing both unfermented and fermented vegetable Juices.*

18. (1.) We melted Brimstone in an Iron Ladle, and dipping slips of coarse linnen Cloth therein, thus made what the Wine-Coopers commonly call Match. (2.) We took a slip of this Match, and setting one end thereof on fire, put into the Bung-hole of a Cask, which being at first loosely stopped, suffer'd the Match to burn nearly out. Then the Bung being driven in tight, we set the Cask aside for an hour or two; and found that this Operation communicates a violently pungent and suffocating Scent to the Cask, with a considerable Degree of Acidity, which is the Gas and acid Spirit of the *Sulphur*. We now filled the Cask with a very small Wine, which had scarce finished its Fermentation; and bunging it down tight, we put in a proper place to clarify. *Matching or Fumigating with Brimstone.*

19. This is the common Method of matching Casks for Wines, but particularly for Stums. It is an useful Experiment, for poor Wines cou'd scarce be kept potable a few Months without it; nor cou'd Stums be prepared in large quantities by any other Method commonly known.

20. By *Stum*, we understand the unfermented Juice of the Grape, several times rack'd, and drawn from its Sediment; the Cask being every time thus fumigated with Brimstone, to prevent the Liquor from fermenting, as it wou'd otherwise readily do, and so become Wine. 'Tis the Fume of the burning Sulphur thus stops all Tendency to Fermentation, and continues the natural Juice of the Grape in a sweet state, fit to be readily *Stum what.*

dily mixed with Wines inſtead of Sugar; fo which purpoſe it is very much uſed in *Holland* and other Countries; as alſo for giving a ne *Fret*, or Briskneſs, to decayed Wines: ſo tha very large Quantities of this Stum are annuall imported to all parts along with the Foreig Wines. And after the ſame manner a Stum prepared in *England* from the Juice of Apple which ſerves the ordinary purpoſes of the Win Cooper.

*Inconveniences of Matching.* 21. The principal Inconveniences in this Me thod of matching the Cask, are theſe; (1.) tha it communicates a nauſeous ſulphureous Taſte an Smell to the Wine; and (2.) is not applicable t red Stums, or red Wines, without greatly im pairing, or almoſt deſtroying their Colour; whenc the Stums in common uſe are always white, th Produce of white Grapes. And becauſe this Me thod of Matching does not ſuit with red Wines hence it is, that all red Wines are uſually doſe with Brandy, in order to preſerve them. An for Wines in general, it might very well ſuffic to burn a little Spirit of Wine in the Cask; an if they want Strength, or Spirit, to preſerve ther ſound, to add Brandy, or Spirit of Wine, pro portionably. By which means they may be pre ſerved without any nauſeous Smell, or Taſte which always attend the way of matching; tho matched Wines loſe of their ſulphureous Taſt and Odour by long keeping. But for Stum there is no other way commonly known and prac tiſed, to preſerve them, but by uſing the Fume of Sulphur.

*The Experiment extended.* 22. The Experiment however is almoſt gen ral, and may to advantage be applied in the ca of all fermented Liquors, and again to unfermente veg table Juices; ſuch as thoſe of Citrons, Quin ces, Oranges, &c. which it prevents from run nin

ning into Fermentation, or Putrefaction. And this Effect it chiefly ſeems to have, by ſtiffening the Air, or adding to its natural Elaſticity *. For as all vinous Fermentation is found to generate Air; ſo the burning of Sulphur, is found to ſtiffen or deſtroy Air. And hence it ſeems to be, that the Fume of burning Brimſtone readily checks the Fermentation of Liquors; ſo that if a Cask, by fretting or fermenting, appears ready to burſt its Hoops, a Diſh of burning Brimſtone held under it, will ſoon quell the Motion: which is one known Method of checking or ſuppreſſing vinous Fermentation.

## Experiment III.

### *The Method of Curing vegetable Juices by Decoction, or Inſpiſſation.*

23. We made an Infuſion of Malt, in the common manner of Wort, for Beer, or Ale; then letting it ſtand to clarify, we decanted the clear, and boiled it over a ſoft Fire, to the Conſiſtence of Treacle: in which ſtate it will long keep ſound, or fit for the making of Beer, Vinegar, or inflammable Spirit. *Wort inſpiſſated.*

24. This Experiment ſhews us a general way of reducing fermentable Subjects to a ſmall Compaſs; and of ſecuring them againſt external Injuries. And thus a kind of Treacle from Malt might be procured in cheap Years, for the ſervice of the Vinegar-maker, the Brewer, and Diſtiller. The Method is likewiſe applicable to any other ſweet or ſaccharine Juice; as that of Grapes, the Tappings of Trees, and the fermentable Juices of Summer-Fruits; and certain ſweet Roots, as Parſnips, *&c.* *The Experiment extended.*



* See Mr. *Hale's Vegetable Staticks.*

25. These inspissated Juices, if not boiled too high, or scorched in the Operation, are easily brought back to a true degree of thinness with Water, and fermented in the same manner, and for the same purposes, as they might have been before they were boiled. So that Beer, Vinegar, or Spirits, may be thus commodiously procured, even in hot Climates. Whence it should seem, that Brewers and Distillers might reap some advantage, by a prudent Use of this Expedient.

26. The Wine-Merchants might thus order the Juice of Grapes, or Stum, to be boiled down in Wine-Countries; and so left fit to be reduced, by Water, and fermented into Wines in others. And for this purpose, the poorer Vintages might serve, as well as the rich; excepting only that the Rob, when reduced by Water, would not afford so much Wine, as the thicker or richer Juices. But the Operation must be performed with considerable exactness, to make it succeed, so as to produce artificial Wines, perfectly like the natural.

27. This Process also seems applicable to *Hops*; which may be thus, in cheap Years, made into a kind of Extract, without any loss of their valuable Parts; whereby the numerous Contingencies attending that Commodity, might in good measure be prevented. But there would here be danger of Fraud; because the Extract of Gentian, Centaury, or other bitter, stomachic Vegetable might be mixed with the Extract of Hops, so as not to be easily discover'd. Tho' perhaps this Inconvenience is not greater than that generally suffer'd already; for many, no doubt, are well assured by experience, that the Extract of Gentian is a wholesome Bitter, which will very well supply the place of Hops in Brewing.

28. It also is a Process somewhat of this kind, that they frequently practise in Wine-Countries

*viz.*

*viz.* either by ſuffering the Grapes to grow almoſt dry upon the Vine; or elſe to boil down their Juice, 'till it becomes ſufficiently thick to afford ſuch rich Wines, as *Canary*, or *Frontignac*; whoſe Strength may be readily imitated by adding a leſs Proportion of Water to the Rob, or boiled down Juice of Grapes, in the manner above explained *.

29. Before we quit this Proceſs, we would recommend its trial upon the Juice, that may be eaſily expreſſed from a vegetable Subject commonly thrown away as uſeleſs: we mean the Shells of green Peaſe; which by being barely boiled in Water, communicate a ſaccharine Sweetneſs thereto; ſo that the Liquor has been made into tolerable Drink, and a good Spirit.

## Experiment IV.

*A Method of curing Yeaſt, the Flower of Wine, and Wine-Lees; for the Service of Diſtilling, Wine-making, Vinegar-making,* &c.

30. We took a quantity of common Ale-Yeaſt, and putting it into a cloſe Canvas Bag, gently ſqueezed out the Moiſture in a Screw-Preſs, 'till the remaining Matter was left as hard as Clay; in which ſtate, being cloſe packed in a tight Cask, and well ſecured from the Air, it will keep freſh and ſound for ſeveral Months, as has been often experienced. *Yeaſt cured and preſerved.*

31. This is an Experiment of conſiderable Uſe to Brewers and Diſtillers, who in *England*, tho' they employ very large quantities of Yeaſt, ſeem to have no good Method of preſerving it, or raiſing Nurſeries thereof; whereby they ſuſtain a conſiderable Loſs. Whereas the Brewers in *Flanders* make a great Profit, by ſupplying the Malt- *Uſes.*



* §. 23—27.

Distillers of *Holland* with Yeast, which is render'd lasting and fit for Carriage, after the manner of our present Experiment.

*The Experiment extended.*

32. The same Method is practicable to much greater advantage in the Yeast of Wine and Wine-Lees; if they cou'd be imported into *England*. For by this means we might easily imitate the Wines and Brandies of foreign Growths: the Lees and Yeast of Wine readily affording an essential Oil, by Distillation; a small Proportion whereof will flavour a large one of Wine or Brandy. But a shorter and more perfect way is to let any tasteless, or other proper Wine, fret or stand, for some time, upon such Lees, or Wine-Yeast, whereby it will to great advantage acquire the natural Taste and Flavour of the Wine, whereto the Lee, or Yeast, belonged.

*Perfect Curation what.*

33. Thus we have given a few Examples of *Vegetable Curation*, whereon the Improvement of several Arts depends: We cannot go through all the Species of it, which would be an immense Labour; nor are Men hitherto arrived at the perfect Method of preserving Vegetables in their natural Form, with their Colours, Odours, and all the sensible Qualities, for any number of Years. Yet something considerable might be done in this way, by proper Application. Fruits may long be preserved fresh in Spirit of Wine, first well saturated with the Skins and tinging parts of the Fruit. And many of them may be tolerably preserved in perfectly fermented Liquors, which generate no more Air. The more solid kinds of Substances may be commodiously cured, by gentle drying them in the Sun, Shade, or other slack Heat. Thus Pease, or Beans, being dried young in a slack Oven, in their proper Season; may be boil'd green and tender, in the Winter, almost like those new gather'd. Certain ways of

pre-

preſerving Fruits, and other vegetable Subjects, both in a dry and moiſt form, with Sugar, are now generally known: But there are ſome extraordinary means of curing ſeveral kinds of Bodies reſerved as Secrets by Artiſts. Tho' even theſe might be exceeded, if we had a thorough Knowledge of the preſent Subject; which might alſo be extended to the animal Kingdom, under the Name of *Animal Curation*, the compleat Art whereof, would prove highly uſeful at Sea.

## Axioms *and* Canons.

1. We learn from the preceding Enquiry, that Men have power to ſtop the Courſe of Nature in Vegetation, ſo as to make this Principle anſwer their own particular Ends and Deſigns; whence Arts may receive conſiderable Improvements *.

2. That the Art of Malting is farther improveable by a general Acquaintance with the Nature of Vegetation, vegetable Juices, the Art of Fermentation, and the Art of Sugars †.

3. That the Labour and Expence attending the Art of Malting, may, in ſome meaſure, be ſaved by procuring and ſeparating the ſweet Juices of Vegetables, as Nature affords them; or by boiling them down to a Treacly or Saccharine Subſtance ‖.

4. That there are different Seaſons of the Year, peculiarly fitted to the collecting or procuring of theſe Juices, and all other vegetable matters; according as they are required ripe or immature **.



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* See *Exp.* I.
† See *Exp* I. II.
‖ See *Exp.* I. III.
** See *Exp.* I.

5. That the Fumes of burning Sulphur have a great anti-fermentative, anti-corruptive, or preſervative Power upon vegetable Juices *; and this without rendring the Liquors unwholeſome; tho' the Fume is diſagreeable, and of itſelf ſuffocative.

6. That the Fumes of burning Sulphur have a Power of diſcharging the Colour of red Wines †; on which account theſe Fumes are uſually employed for the Blanching of Silks, Flannels, &c.

7. That *Vegetable Curation* chiefly depends upon the Excluſion of the Air, and all ſuperfluous Moiſture; and this either ſingly, or conjointly ‡.

8. That *Vegetable Curation* is the keeping of all the Principles of a vegetable Subject together undeſtroyed, in their natural Texture or Arrangement ‖.

9. That all ſweet vegetable Juices may be preſerved ſound and ſerviceable by Inſpiſſation, over a ſoft Fire; ſo as to throw off their ſuperfluous aqueous Parts, and leave the ſweet or ſaccharine Subſtance behind, in a ſtate fit for Fermentation, upon the addition of freſh Water **.

10. That ſeveral bitter vegetable Juices, capable of anſwering the End of *Hops* in Brewing, may be inſpiſſated by the Fire, and preſerved for that purpoſe ††.

11. That thoſe extremely corruptible Subſtances, Yeaſt, the Flowers of Wine and Wine-Lees, may be preſerved ſound, barely by freeing them from their ſuperfluous Moiſture, and ſecuring them from the external Air, and too great Heat ‖‖.

12.

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* See *Exp.* II.
† Ibid.
‡ *Exp* II, III, IV.
‖ See Ibid.
** See *Exp.* III.
†† Ibid.
‖‖ *Exp.* IV.

12. That the Buſineſs of *Vegetable Curation* may receive great Improvements by a proper chemical Enquiry, made with a direct View to this Subject; from whence many farther advantages are derivable to Arts and Trades, particularly to the Sugar-Colonies abroad, to Brewers, Wine-makers, and Diſtillers in hot Countries; and that the Enquiry likewiſe might be advantageouſly extended to *Animal Curation* *.

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* See *Exp.* IV.

# LECTURE XI.

## CONTAINING,

*Ways of illuſtrating and improving the Arts depending upon* Vegetable FERMENTATION; *particularly*, Brewing, Diſtilling, Vinegar-making, &c.

*The Subject.*

1. IN our laſt Lecture we endeavour'd to ſhew the Method of procuring certain vegetable Commodities, and preſerving them uncorrupted, for the Service of Arts: In our preſent, we ſhall conſider ſome Uſes of theſe Commodities, when thus preſerved; or the Ways of employing them, ſo as to afford various Preparations for the commodious carrying on of Trade, and the Buſineſs of ordinary Life.

2. As our Conſideration is reſtrain'd to the vegetable Kingdom; the Arts that will chiefly come before us at preſent, are thoſe of Wines, Sweets, Malt-Liquors, Vinegars, and Brandies; in all which we have already made ſome progreſs*. But there remains much behind, for the Improvement of theſe Arts; which lie in a State, far from that of Simplicity, whereon their Perfection ſeems to depend.

*The Deſign of the Experiments.*

3. Theſe Arts we ſhall here endeavour to improve by four direct Experiments: The *firſt* whereof is capital, and calculated to ſhew the Method of reducing vegetable Juices, cured by Decoction,

* See *Lect.* X.

Decoction, or Inſpiſſation *, back to a State for affording Vinegars, Wines, and Brandies, by Fermentation; and at the ſame time to exhibit a new Method of making an artificial *Muſt*, or *Stum*, as good as the natural; and fit for the refermenting, fretting, improving, and making of Wines, Vinegars, and Spirits, in all Countries.

4. The *ſecond* Experiment will exhibit the common Methods of forcing, or fining down fermented vinous Liquors, ſo as to render them expeditiouſly bright, or clear, and fit for Uſe.

5. The *third* Experiment will ſhew a Method of converting White Wines into Reds; and of recovering, or improving, the Colour of decay'd red Wines. The *fourth*, a Method of concentrating Wines, Vinegars, or Malt-Liquors, for Carriage, or Exportation.

6. The *fifth* will ſhew a Method of recovering prick'd Wines; and the *ſixth* and laſt will ſhew a more profitable Method than that commonly uſed in *England*, of fermenting Malt for Diſtillation, or the Production of common inflammable Spirits.

Theſe Experiments now follow in their Order.

## Experiment I.

*To ſhew the Method of reducing vegetable Juices, cured by Inſpiſſation, or Decoction, back to a State fit for affording Wines, Vinegars, and Brandies, by Fermentation: and at the ſame time to exhibit a Method of making an artificial Muſt, or Stum, as good as the natural; fit for the refermenting, fretting, improving, or making of Wines, Vinegars, and Spirits.*

7. We took three Pounds of white Lump Sugar, which had been well cleanſed of its Treacle; and *Artificial Muſt prepared.*

* See *Lect.* X. *Exp.* III.

and melting it in three Quarts of fair Water, added in the boiling half an Ounce of finely pulverized *Rheniſh* Tartar; which diſſolved with a remarkable Ebullition, and gave a grateful Acidity to the Liquor. Then taking the Veſſel from the Fire, and ſuffering it to cool, we thus procured a *Muſt*, which in all reſpects reſembles the natural tart and ſweet Juice of a white flavourleſs Grape; when that Juice is well purified, and often racked from its Sediment, in order to make *Stum*. And if our artificial *Muſt* be ſtummed that is matched, or well fumigated with burning Brimſtone, after the manner ſhewed in our laſt Lecture *, it thus becomes a perfect *Stum*; which may be made of any Flavour, at the diſcretion of the Artiſt.

*Uſes.* 8. This Experiment is ſo pregnant, that it might deſerve to have its Uſes explained by an expreſs Treatiſe †. It affords abundant Inſtruction for improving the Art of Sweets, Stums, Wines, Vinegars, and Spirits; it likewiſe affords ſome uſeful Inſtructions about the nature of ſweet and tart vegetable Juices; and the ways of imitating them by Art. But theſe particulars we can only juſt touch upon for the preſent.

*The Experiment how deduced.* 9. The Experiment itſelf was form'd upon the Analyſis of the Juice of the Grape before Fermentation; which Juice, to the Senſes, appears no other than a ſaccharine Subſtance diſſolved in Water, with the addition of a tartarous Acid. And as this is fully confirmed by a chemical Reſolution; it was hence eaſy to expect, that if Tartar, which is the natural Salt of Wine, or of any ſweet vegetable Juice fermented, cou'd be artificially diſſolved in a proper Mixture of Sugar and Water, it would give an exact Reſemblance

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* *Exp.* II.

† See the Appendix to this Lecture.

of the thing. And upon trial it was found, that Tartar might be thus diſſolved, ſo as to communicate an agreeable Acidity to Sugar; and thus to imitate, in great perfection, the natural ſweet Juices of Vegetables, without their particular Flavours: and hence our Experiment diſcovers to us the Nature, Uſe, and Perfection of the Art of *Sweets*.

10. By a *Sweet* is underſtood any vegetable Juice, whether obtained by means of Sugar, Raiſins, or other Foreign or Domeſtick Fruit, which is added to Wines, with a deſign to improve them. Whence we ſee, that the Art of Sweet-making might receive a high degree of Improvement, by uſing pure Sugar, as one general wholeſome Sweet, inſtead of thoſe infinite Mixtures of Honey, Raiſins, Syrups, Treacle, Arrum, Cyder, *&c.* wherewith the Sweet-makers ſupply the Wine-Coopers, to lengthen out or amend their Wines. For pure Sugar being added to any poor Wine, will ferment therewith; improve it, and bring it to a proper degree of Strength and Vinoſity. If the Wine to be thus mended is tart of itſelf, no Tartar ſhould be added to the Sugar: but if it be too ſweet, or inſcious, then the Addition of Tartar is proper. *A Sweet what.*

11. The preſent Experiment adds no leſs Improvement to the Art of *Stums*; which Art may perhaps be hence brought to its Perfection. And here we deſire the Men of Buſineſs would duly reflect, that wherever Sugars go, there go in a ſolid form *Stums*, *Wines*, *Vinegars*, and *Brandies*; that is, the actual Matter out of which, by the bare addition of Water, theſe ſeveral Commodities may be readily prepared. For it is by no means neceſſary, that Sugars ſhould be imported and exported in a liquid Form, for the making *Extended.*

of

of Stums, Wines, &c. becauſe it is ſo eaſy to a
the Tartar and Water, at any Port they arrive a

*Farther Uſes in the Trade of Wines.*

12. Our Experiment alſo points out the w
of perfecting the *Art of Wines*, by reducing
component Matter thereof to a ſmall Bulk; a
occaſionally bringing it back with Water int
Muſt, in any Climate; which Muſt may
there tinged of any Colour, or impregnated w
any Flavour; ſo as to be fermented into a W
of any Species, or Denomination. Thus i
few Drops of the eſſential Oil of Nutmeg,
Cinnamon, were to be rubbed with a little Sug
or into a kind of *Elæoſaccharum**, and then mix
with our artificial Muſt, or Stum, the W
made of it would have a very grateful Odour a
Flavour. And ſo if an eſſential Oil were p
cured from the Lees of any particular Wine, a
introduced into our artificial Stum, after the fa
manner, the artificial Wine wou'd thus have t
Odour and Flavour of the natural Wine that
forded the Lees; bating for the Roughneſs, Fir
neſs, or Dryneſs given by the Husk and Sto
For an artificial Muſt has no Flavour, or C
lour of its own; but readily receives, and
comes impregnated with either by Art. And h
far this Experiment may be uſeful in teaching
Method of making a rich concentrated Wi
for the extemporaneous Improvement of t
poorer Sorts, or for making a ſerviceable ki
of extemporaneous Wine, barely by mixing wi
Water; we recommend to the Trial of thoſe w
have a Talent at this kind of Experiments.

*And Vinegars.*

13. The Art of *Vinegar-making* may alſo p
ſibly receive a high Degree of Improvement,
means of the preſent Experiment; as it affords
a Method of diſſolving Tartar in Water,
which the whole Art of Vinegar-making ſeems
depen

* See hereafter *Lect.* XIII. *Exp.* IV.

epend. For there are many phyſical and che-
ical Reaſons and Experiments, to ſhew that
inegar is no more than a particular kind of
*uid Tartar.* And the Art of making Vinegar
ou'd then be perfect, when it could readily, or
temporaneouſly, prepare and concentrate the
ommodity; ſo as to give it a kind of ſolid or
nſiſtent Form, which ſhould render it durable,
ing it into a ſmall Bulk, and leave it fit to be
duced by Water into a fluid Form, for uſe in
l Climates.

14. We plainly ſee, that the original compo-
nt Matter of Vinegar, which is Sugar, lies in
mall Bulk, and may be readily converted by
ater, Air, and Heat into Vinegar *. Sugar
the Act of *Acetification* ſeems wholly converted
o a fluid Tartar; and if the aqueous Liquor
ſeparated from Vinegar, we find the Vinegar
hereby render'd the ſtronger: inſomuch that
Vinegar were to be highly concentrated by
ngelation, it would become almoſt ſolid, or
kind of actual Tartar. Whence the Rule is
y, that in order to make an almoſt ſolid Vi-
gar, we ſhould endeavour to diſſolve Tartar
an aqueous Liquor. Whence, for perfecting
Art of Vinegar-making, we recommend
diſſolving of Tartar largely with Sugar, or
eacle, and the ſtrongeſt Vinegar, by repeated
bibitions, Heat, and a proper Management.

15. We proceed to ſhew ſome Uſe of our Ex- *In the Di-*
iment in the Art of Diſtillation; which Art *ſtillation*
wiſe might poſſibly arrive at Perfection by its *of Spirits.*
ans. 'Tis generally known, that a taſteleſs,
ourleſs, yet perfectly vinous and cheap Spirit,
he grand Deſideratum in the Art of Diſtilling:
w ſuch a Spirit ſeems eaſily procurable from
Stum, made highly acid by the addition of
Tartar,

* See *Lect.* VI. *Exp.* II.

Tartar, and fermented 'till that Acidity preva
as it ſoon will do, ſo as to prove a true *Vino*
And thus a highly vinous, yet flavourleſs Spi
may be obtained at a very reaſonable Charge
a Man thoroughly underſtands the Art of F
mentation. And ſuch a Spirit might be reac
flavoured and converted into *French Brandy*,
rack, or any other kind of Spirit, that commo
ſells for a much greater Price *.

*Farther Uſes.*

16. Theſe Particulars, with ſeveral others t
might be mention'd, hold of our Experimen
its perfect State: for to reduce ſweet vegeta
Juices to a pure white Sugar, without any P
ticipation of Treacle, is an extreamly *perfect*
*ration*, which coſt much labour before it
diſcover'd. But now the thing is common,
almoſt ſeem to neglect it; at leaſt do not enq
into the farther Uſes of ſo capital a Diſcove
to the apparent Detriment of the *Sugar-Tra*
and the Colonies thereon depending.

17. The Curation by bare Decoction, or
ſpiſſation, is of a lower Claſs, tho' that ſtill
its Uſes †; for even Treacle is an uſeful S
ſtance: But the Rob of Malt, as we ſhew'd
our laſt Lecture ‖, may be employed for
making of Beer, Ale, Vinegar, and Spirit
all Climates, after the ſame manner as we h
mention of Sugar. And the Perfection of t
Curation would be, to reduce all ſuch Robs
an actual Sugar; as with skill we appreh
might be done to advantage. Tho' as ſo
Countries and Palates prefer Malt-Liquors,
Corn-Spirits, to Wines and the fineſt forei
Brandies; this Art of Sugar-making need not
univerſally extended to Malt and Grain.

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* See hereafter *Lect.* XII.

† See *Lect.* X. *Exp.* III.

‖ Ibid.

18. Many other Uſes are derivable to Arts nd natural Philoſophy, from our preſent Expe- riment; but we have only time to mention one more. We ſee that Stums, Wines, Vinegars, nd inflammable Spirits, of all ſorts, may be ommodiouſly obtained by its means; we now dd, that the original Matter of them all may be educed to a brown thick treacly, or other co- our'd Subſtance, whether red, yellow, or black; nd exported under this diſguiſed Form to any rading Part of the World, for preparing theſe ommodities there. And thus the Country poſ- ſs'd of Sugar, might advantageouſly ſupply many thers with matter for exerciſing of ſeveral Arts; r the Production of Wines, Beers, Vinegars, nd Brandies. And in the ſame manner might amilies be ſupplied with an artificial Muſt, Stum, r Rob of Grapes, for making any ſort of Wine home, with much greater eaſe than they now ew Beer: for the expert Artiſt will eaſily give e proper Flavour and Colour of any Wine*, this artificial Muſt, or Rob; ſo that there ould be nothing more required at home, for e making it into Wine, than to add the Water d the proper Ferment in the Cask.

## Experiment II.

*e common Method of Forcing or Fining down fer- mented vinous Liquors, ſo as to render them ex- peditiouſly bright, or clear, and fit for Uſe.*

19. We took an Ounce of fine Iſing-Glaſs, *Wine fined.* t with a Hammer into Shreds, and diſſolved ver the Fire, by boiling, in a Pint of Water, ereby it became a ſtiff Gelly when cold. Some this Gelly we whisked up into a Froth, with

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* See above §. 12. and hereafter *Exp.* III.

a little of the Wine intended to be fined; the ſtirred it well among the reſt in the Cask, ar bunged it down tight. By which means th Wine will uſually become bright in eight or te Days.

*Uſes.* 20. This Method is beſt ſuited to white Wines but for red ones, the Wine-Coopers common uſe the Whites of Eggs, beat up to a Froth, ai mixed in the ſame manner with the Wines. Ai theſe are the common Methods of Forcing at pr ſent uſed in the Wine-Buſineſs.

*Rationale.* 21. The phyſical Reaſon of the Experiment this; that the Bodies here employed as the Forcin are viſcous or glutinous; ſo as to entangle thei ſelves among the flying Lee, or light Feculenci that float in the Wine; and thus forming a M ſpecifically heavier than the Wine, ſink thro' t Body thereof, like a Net, carrying all the Fo neſs it meets with in its way to the bottom. I when the Wine is extremely rich, ſo that its ſp cific Gravity proves greater than the Maſs forn of the *Forcing*, as it is called, and the Dregs, Lee; this Maſs riſes upwards, and floats on top of the Wine, in which Caſe alſo the W will draw off fine.

*Inconveniencies of the Method.* 22. The principal Inconvenience of this M thod of fining Wines, is its Slowneſs; as not h ing its effect in leſs than a Week, or ſometi a Fortnight, according as the Weather proves vourable or unfavourable, cloudy or clear, wi or calm; which appears to be Matter of conſt Obſervation. But the Wine-Merchant frequen requires a Method that ſhall with certainty m his Wines fit for taſting in a few hours. An Method of this kind there is, but kept as a v able Secret in a few hands. Perhaps it depe upon the prudent uſe of a tartarized Spiri Wine, and the common Forcing, as Acceſſo

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along with *Gypsum*, or coloured Alabaster, as the Principal; all which are to be well romaged, or stirred together in the Wine, for half an hour, before it is suffer'd to rest.

23. Let it be here observed, that all Wines, Malt Liquors, and Vinegars, which are well made, and perfect in their kind, will grow fine of themselves, barely by standing; so that if they do not thus grow fine in a reasonable time, it is a sign they labour under some Disease; that is, are either too aqueous, too acid, too alkaline, tend to Putrefaction, or the like. In all these Cases, which may be properly enough called the *Diseases of Wines*, suitable Remedies are required, before the Wines will grow fine. *Fining not always necessary.*

24. To enquire particularly into the Diseases, with their respective Cures, in fomented Liquors, is not the present Design *: only we must observe, that the most general Remedy hitherto known, for all the Diseases of Wines, is a prudent Use of tartarized Spirit of Wine; which not only enriches, but disposes all ordinary Wines to grow fine. But Wines well prepared, in the Method above mentioned, from artificial Must, are subject to no Diseases. And even those obtained in the common way may be effectually secured against all Diseases by Congelation, which takes away their superfluous Water, without prejudice to their vinous parts †. *Diseases of Wine how cured.*

25. Skimmed Milk likewise is a proper Fortning for all white Wines, Arracks, and small Spirits, but improper for red Wines; because it discharges their Colour. Thus if a few Quarts of well-skimmed Milk be put to a Hogshead of *The Use of Milk in Wines.*



* See the Appendix to this *Lecture*.
† See below *Exp.* IV.

red Wine, it will ſoon precipitate the greateſt part of the red Colour, and leave the Liquor much paler, or almoſt white. Whence this Experiment ſometimes becomes of uſe in turning prick'd red Wines into Whites; where a ſmall Degree of Acidity is not ſo much perceived. And on this Property of Milk depends that other, of kin thereto, whereby it whitens Wines, that have acquired a brown Colour from the Caſk; or by haſty Boiling, before they were fermented: For in theſe Caſes, the addition of a little ſkimmed Milk, will alſo precipitate the brown Colour and leave the Wines almoſt limpid, or of what they call a *Water Whiteneſs*; which is much coveted abroad in white Wines, as well as in Brandies.

## EXPERIMENT III.

*A Method of converting White Wines into Reds and of reccovering the Colour to decay'd red Wines.*

*White Wine colour'd red.*

26. We put four Ounces of what is commonly called *Turnſol Rags*, into an earthen Veſſel, and poured upon them a Pint of boiling Water; then covering the Veſſel cloſe, and ſuffering it to cool we afterwards ſtrained off the Liquor, which was found of a very deep red Colour, inclining to purple; ſo that a ſmall proportion hereof would give a beautiful bright red to a large proportion of white Wine, mix'd therewith.

*The Experiment improved.*

27. This Tincture might be mixed with Brandy or made into a Syrup with Sugar, for keeping. But the uſual way with the Wine-Coopers and Vintners is to infuſe the Rags cold in Wine, for a Night or more, and then wring them with the hands. But the Inconvenience of this Method is, that it gives the Wine a diſagreeable Taſte

or what is vulgarly called the *Taſte of a Rag*: whence the Wines thus coloured uſually paſs among the Judges for *preſſed Wines*; which have all this Taſte from the Canvas Rags, wherein the Lees are preſſed.

28. The way of infuſing the Rags in boiling Water, is not attended with this Inconvenience; but then it loads the Tincture with Water, which may prove prejudicial to the Wine; or if made into a Syrup, or mixed with Brandy, the Colour is thus diluted, or weaken'd; ſo that a large quantity of theſe additional Ingredients comes to be uſed with a ſmall one of the Colour, which alone is the Thing required.

29. Hence the Buſineſs of colouring Wines red, is attended with conſiderable Inconveniencies, in thoſe Countries that do not afford the *tinging Grape*; which yields a Blood-red Juice, wherewith the Wines of *France* are often ſtained. In defect of this, they ſometimes uſe the Juice of Elder-Berries, and ſometimes Logwood at *Oporto*; when their Wines are not naturally red enough; for this Colour, it ſeems, they muſt have, to make them ſaleable. *Inconveniencies.*

30. The Colour afforded by our preſent Experiment is not properly the *Port*, but the *Bourdeaux-Red*, that does not ſo well ſuit with *Port-Wines*: Whence the Foreign Coopers are often diſtreſſed for want of a proper Colouring to their red Wines in bad Years. We wou'd, therefore, recommend to them the Uſe of an Extract made by boiling *Stick-Laque*, in Water; which gives a rich Red, that comes tolerably cheap; and is, perhaps, the perfect red *Port*-Colour *. But if this proves unſatisfactory, let a Method be tried *Remedies.*



* See hereafter *Lect.* XIV. *Exp.* II.

of making a Laque out of the Skins of the tingin Grapes, or *Raiſins de Teinte.* Cochineal migh likewiſe anſwer the purpoſe, tho' it loſes of i Colour by mixing with all acid Wines. Elde Berries give this Colour in a tolerable Degre but not without communicating a nauſeous Fla vour.

31. The Produce of our preſent Experimer might anſwer well, if the Colour could be ha pure, or made up into Cakes, without being im bibed by Rags; for it is very eaſy to obſcure i too great Brightneſs, or vivid purple Briſkneſ by the addition of a little burnt Sugar, Rob Sloes, Rob of Oak, Rob of Wine, or any oth Colour bordering upon the tawny, ſo as to mak a true *Port*-Colour.

## EXPERIMENT IV.

*A Method of condenſing, or concentrating Wine Vinegars, and Malt-Liquors, for Exportation.*

*Wines and potable Liquors improved by Freezing.*

32. We took a Quart of ordinary red Por Wine, included in a *Florence* Flaſk; and placin the Flaſk in a Mixture of one part common Sal and two parts Snow, or beaten Ice; we foun the more aqueous part of the Wine was ſoo turned to Ice; thro' which, by a bare Inclinatio of the Glaſs, the thick, rich, or more vinous pa of the Wine, was eaſily drained, by inclining th Glaſs.

*The Experiment regulated.*

33. This Experiment is here perform'd to quick, ſo that ſome of the thick and valuab parts of the Wine are catched, and detained the Ice. To perform it in perfection, the natu ral freezing Cold ſhould be employ'd; by whic means, Wines, Vinegars, and Malt-Liquors ma

be reduced to a fourth of their ordinary Bulk, without any conſiderable Loſs of their eſſential Parts; little more than the uſeleſs, or detrimental Water being thus ſeparated, ſo as to leave all the eſſential Parts of the Wine admirably *cured*, or capable of remaining perfect, for ſeveral Years, as has been found upon Trial. And by a prudent Uſe and Application of this Experiment, we conceive that great Improvements might be made in the Wine-Trade.

34. For by a proper Contrivance, and a little Dexterity, which may be eaſily gain'd by Experience; large quantities of the pooreſt Wines might be thus, at little Expence, reduced to rich ones, ſo as to increaſe their value, in proportion to the Diminution of their Bulk. And thus alſo, by repeating the Operation, might extremely rich, and generous Wines, or a true Quinteſſence, be procured, for the Amendment of the thinneſt and pooreſt Sorts. And in this view it ſhould be remember'd, that mountanous Wine-Countries are often furniſhed with Snow, by means whereof artificial Freezing might be practiſed in the time of Vintage: barely to intimate which, may give a ſufficient Hint for introducing a new and uſeful Branch of Buſineſs; as Wines may be hence concentrated after Fermentation, no leſs commodiouſly than the Juice of the Grape, before that Operation *. And if to this be added, that the *Art of Congelation* is alſo capable of Improvement from a proper Uſe of *Sal Ammoniac* and Water †, whilſt the *Sal Ammoniac* remains eaſily recoverable, it ſhou'd ſeem that little more than a ſuitable Apparatus is requiſite to bring this matter

* See *Lect.* X. *Exp.* III.
† See *Lect.* V. *Exp.* II.

matter to perfection, with all desirable Advantages.

### EXPERIMENT V.

### *A Method of recovering prick'd Wines.*

*Prick'd Wine recover'd.*

35. We took a Bottle of prick'd red *Port*-Wine, and added to it about half an Ounce of tartarized Spirit of Wine; then shaking the Liquor well together, we set it by for a few Days, expecting to find it remarkably alter'd for the better; as upon Trial it afterwards appear'd to be.

36. This Experiment depends upon the useful Doctrine of *Acids* and *Alkalies* *. All perfect Wines have naturally some Acidity, and when this Acidity prevails too much, the Wine is said to be *prick'd*; which is a State of the Wine tending to Vinegar †. But the prudent Introduction of a fine *alkaline Salt*, such as that imbibed by Spirit of Wine, digested upon Salt of Tartar, (whereby the tartarized Spirit of Wine is prepared) has a direct power of taking off the Acidity; wherein the Spirit of Wine also contributes, and is in other respects a great Preservative of Wines ‖. And if the Operation be dextrously perform'd, prick'd Wines may be thus recover'd, and made to remain sound and saleable for some time. And the same Method is applicable to *hard* Malt-Liquors, or such as are but just turn'd sour, and not almost become Vinegar.

37. An Expedient of the same nature is frequently made use of, to recover sour Small-Beer, by

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* See these Terms explained in the *Glossary* prefixed to these *Lectures*.

† See *Lect.* VII. *Exp.* II.

‖ See *Lect.* VII. *Exp.* IV. and the Appendix to the present *Lecture*.

by adding a little Chalk, or Powder of Oyſter-Shells thereto: for Chalk and Oyſter-Shells being terreſtrial Alkalies, immediately take off the too great Acidity of the Liquor; and cauſing an Ebullition therewith, give it a conſiderable Briſkneſs, if drank before the Ebullition is entirely finiſh'd. To continue which the longer, it is beſt to add the Chalk, or Oyſter-Shells, whole to the Liquor in the Caſk; Care being taken to drink it out ſoon, otherwiſe the Liquor will ſpoil *.

## Experiment VI.

*A more profitable Method, than the common, of fermenting Malt for Diſtillation, in order to obtain from it a Brandy, or inflammable Spirit.*

38. We took ten Pounds of Malt, reduced to fine Flower, and three Pounds of common Wheat-Meal; to theſe we added, firſt, two Gallons of cold Water, and ſtirred them very well together; then five Gallons of Water, boiling hot, and ſtirred all very briskly together again. Letting them now ſtand, for two hours, we repeated the Stirring again; and when the whole was grown cold, we added to it two Ounces of ſolid Yeaſt; and ſet it by, looſely cover'd, in a warmiſh Place to ferment †. *Brewing for Diſtillation.*

39. This Experiment exhibits the *Dutch* Method of preparing the *Waſh*, as it is called, for Malt-Spirit; whereby they ſave much trouble, and procure a large Yield of Spirit; thus commodiouſly reducing the two Buſineſſes of Brewing *Uſes.*

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* See *Lect.* VII. *paſſim*.
† Ibid.

ing and Fermenting, to a ſingle Operation. I *England*, the Method is to brew and maſh fo Spirit, as they ordinarily do for Beer; only in ſtead of boiling the Wort, they pump it int large Coolers, and afterwards run it into thei fermenting Backs, to be there work'd, or fer mented with Yeaſt; thus beſtowing twice as muc Labour in the Operation, as is required; and a the ſame time loſing conſiderably of their quan tity of Spirit, by leaving the groſs Bottoms ou of the Still, for fear of burning.

*And Advantages.* 40. In the manner of our preſent Experiment where the Malt is ground fine, we have all it fermentable parts let looſe, ſo as at once to mi with the Water. And we can thus put all th *Bottoms* into the Still, without danger of burn ing; becauſe being render'd ſo fine at firſt, they entirely loſe their Clamminеſs in the Fermen tation, ſo as to become light, or buoyant; an thus increaſe the Yield of the Spirit.

*Regulation.* 41. The Meal of unmalted Corn is found ne ceſſary to be mixed along with the Malt, to pre vent its over-fermenting; and throwing off th matter of the Spirit. But as Diſpatch is here par ticularly required, to avoid Expence, and a larg Apparatus of Veſſels; a conſiderable quantity o Yeaſt is added to quicken the Fermentation, ſ that it may be finiſhed in two or three Days.

42. More Yeaſt ſhould be added, if the Wea ther be cold, and leſs if it be hot; the Converſ is to be underſtood of Meal, more whereof is re quired in hot Weather to check, and leſs in cold to haſten the Operation; which in the preſen Caſe is deſign'd to be violent, contrary to wha ought to be obſerved in the Fermentation fo Wines; where the ſlower the Operation is per formed

formed, the better the Liquor will prove. Which Rule may likewiſe obtain here in a leſs degree: for it is poſſible to ferment the Waſh ſo violently, that it ſhall ſoon end in Putrefaction *. And thus by rightly conducting the ſeveral parts of the Proceſs, we may, by Diſtillation, procure all the Spirit that Malt and Meal are capable of affording by Fermentation. The Method of procuring this Spirit will be ſhewn in our next Lecture †.

## Axioms *and* Canons.

1. We have ſeen in the preceding Enquiry, that excellent Stums, Sweets, Wines, Vinegars, and Brandies, may be prepared from Sugar; in any Climate, where Water and Tartar can be procured ‖.

2. That Malt-Liquors, and Malt-Vinegars, may be commodiouſly prepared in any hot Climate, from the *Rob*, or Treacle, of Malt; which is fit for Tranſportation, ſo as to convey the deſired Virtue of the Malt in a ſmall Bulk; and retain it perfect for ſeveral Years ‡.

3. That the Perfection of the *Art of Vinegar-making* depends upon the Converſion of Sugar into a fluid Tartar; or a Method of permanently diſſolving a large Proportion of Tartar in Water **.

4. That it is poſſible to reduce both Wines and Vinegars to a thick Syrupy Form ††: ſince the



* See *Lect.* VII. *paſſim.*
† See *Lect.* XII. *Exp.* I.
‖ See *Exp.* I. See alſo *Lect.* VII. *Exp.* I.
‡ *Exp.* I. See alſo *Lect.* X. *Exp.* III.
** See *Exp.* I. See alſo *Lect.* VII. *Exp.* II.
†† *Exp.* I, IV.

original Matter of them both, *viz.* Sugar, is so lid; and since they both may be concentrated by Frost, to a high Degree of Richness and Thickness.

5. That a new Art may be introduced of supplying Foreign Countries with a proper, or rich syrupy, or treacly Substance, which shall lie in a small Compass, for the making of Wines Beers, Vinegars, and Spirits, in all Climates with considerable advantage*: A Consideration deserving the Attention of the Sugar-Colonies or their Mother-Kingdoms.

6. That the sweet and tart Juices, such as Summer-Fruits, Cherries, Grapes, *&c.* consist of a saccharine and tartareous Substance; or, to speak explicitly, of an actual Sugar, and an actual fluid Tartar: which affords an useful Rule for improving these natural Juices in bad Years; and again for imitating them by Art; as also for producing Wines, Vinegars, and Brandies, without them where Sugar and Tartar can be procured†.

7. That there is a great Affinity betwixt Sugar and Tartar; since they not only reside together, and are intimately mixed in all sweet and tart vegetable Juices, but also seem readily convertible into each other; for the acid and tart immature Juices of Plants become saccharine by Ripening: Wine made wholly of Sugar, and Water, shoots a large quantity of Tartar, and Sugar is wholly convertible into Vinegar, which is a fluid Tartar. Whence much light might be derived for explaining the Nature of Vegetation Acidity, Sweetness, Immaturity, Ripeness, Vinification

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* *Exp.* I, IV. See also *Lect.* X. *Exp.* III.

† *Exp.* I. See also *Lect.* VII. and X. *passim.*

nification, Acetification, and the Art of procuring Tartar *.

8. That the Improvement, or Perfection, of ſeveral Arts may depend upon a ſingle Experiment; as we remarkably ſee by our ſimple Experiment of diſſolving Tartar in Water and Sugar †; which has a direct Tendency to improve the ſeveral Arts of Sweets, Stums, Wines, Vinegars, and Spirits.

9. That a very large proportion of Water enters the natural Compoſition of Stums, Wines, Vinegars, and Spirits ‡; as plainly appears from hence, that the eſſential Matter of them all is contained in dry Sugar; which being barely diſſolved in Water, and fermented, becomes Wine; or a Liquor that may, by Congelation, be reduced to a fourth, or a ſixth part of its natural Bulk, without any conſiderable Loſs of its valuable Matter, or little more than its ſuperfluous Phlegm, or Water ||.

10. That the Diſeaſes of Stums, Wines, and Vinegars, are owing to an over-proportion of aqueous Parts; ſo that if their Water be taken away, without doing violence to the eſſential Matter, thoſe ſeveral Commodities may be preſerved in a State of Perfection, as we ſee they are by Concentration, or Congelation, which thus advantagiouſly ſeparates their aqueous Parts, without hurting the reſt **.

11. That numberleſs new Sorts of Wines, and Candies, are producible, barely by adding any well-ſcented Vegetable, or their eſſential Oils, or Mix-

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* See *Lect.* VII. and X. See alſo the preſent *Lecture*, *Exp.* I.
† *Exp.* I.
‡ *Exp.* I. and IV.
|| See *Exp.* IV.
** Ibid.

Mixture of ſuch Oils, to a natural or artificia
Muſt in the Fermentation *. And the ſame ma
be proportionably underſtood of the Colours
Wines; which might, by proper tinging Ingr
dients, be thus procured blue, green, yellow,
of other Colours, if it were neceſſary, as well
pale, or red †.

12. That the phyſical Agent in the fining
Wines, and other fermented Liquors, is ſom
proper viſcous Subſtance, that entangles the gro
Particles, and either ſinks with them to the bo
tom, or riſes to the top, ſo as to ſeparate an
keep them from mixing with the Body of the L
quor; and that on this Foundation, better M
thods of fining may be diſcover'd, than thoſe h
therto commonly known and practiſed ‡.

13. That *tartarized Spirit of Wine* is a Remed
for acid Wines; and not only abates their Acidit
but alſo ſtrengthens, and diſpoſes them to gro
fine, when they are thick and turbid ‖.

14. That Milk, deprived of its Cream, w
diſcharge the Colour of red Wine, by precipit
ting the tinging Matter to the bottom; and
likewiſe leſſen, and take off the brown Colou
wherewith white Wines are ſometimes accide
tally tinged **.

15. That the Buſineſs of colouring red Win
artificially, may be improved by a proper Uſe
an artificial Turnſol without the Rags; an E
tract of Stick-Laque, *&c.* but particularly by
artificial Tincture of the Huſk, or Skin, of t
red Grape; or a particular Laque made from t
*Raiſin de Teinte* ††.

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* *Exp.* I. See alſo *Lect.* VII. *Exp.* I.
† See *Exp.* III.
‡ *Exp.* II.
‖ *Exp.* V. See alſo the Appendix below.
** *Exp.* II.
†† *Exp.* III.

16. That it is in the power of Art greatly to accelerate the operation of Vinous Fermentation; ſo as to finiſh the whole in a few days time: But that this ſhould only be done, when a Spirit, and not a Wine, is intended; becauſe ſuch a haſty Fermentation ſubverts or deſtroys the Texture requiſite in vinous Liquors *.

## APPENDIX to LECTURE XI.

### SECT. I.

### *The Theory of Vinous Fermentation.*

1. The extenſive Doctrine of Vinous Fermentation being little regarded, in proportion to its philoſophical and practical uſes, it may be proper in this place to lay down its *Theory*, after a conciſe axiomatical manner (as we are the better enabled to do from the Labour which Dr. *Stahl* has beſtowed upon the Subject †) and ſubjoin a few Obſervations with regard to Practice.

2. *Vinous Fermentation* is an inteſtine motion performed by the inſtrumental efficacy of Water; ſo as to ſtrike aſunder, attenuate, tranſpoſe, and again collect and recompoſe, in a particular manner, the Salt, Oil, and Earth of a fermentable Subject ‡.

3. Fermentable Subjects, therefore, are mixed Bodies; conſiſting of *Salt*, *Oil*, and a *Subtile Earth* §.

4. Theſe compound particles of all fermentable Subjects are ſo ſmall, that when aſunder they become imperceptible to the ſenſes; for

O neither

* See Lect. VII. *paſſim*. See alſo the preſent, Exp. VI. and the following *Appendix*.

† See his *Zymotechnia fundamentalis*.

‡ Conſider all the *Inſtances*, or what ſeems equipollent to them all, Sugar and Water.

§ Into which all fermentable Subſtances are reſolved by a chemical Analyſis.

neither the touch nor the ſight diſtinguiſhes them: Whence being mixed with an aqueous Fluid, they leave it tranſparent. Neither have fermentable bodies any conſiderable ſmell or taſte, beſides the taſte of ſweetneſs.

5. Theſe *Principles* of Fermentation, *viz.* the Salt, Oil, and Earth, muſt of neceſſity be in a compound ſtate; for ſeparation requires connexion *. And by compoſition is not here underſtood juxtapoſition, but a very intimate coheſion of the ſmall and different particles: So that the Salt, Oil, and Earth, in each of theſe little and inſenſible compounds, are in actual coheſion, connexion, and union.

6. When, therefore, any one of theſe *Principles* abounds in an over-proportion for an intimate union, the whole efficacy of the Fermentation is either ſtopped and impaired, or elſe preſently determined, and limited to one certain ſpecies.

7. And this is to be particularly remarked of the volatile or eſſential *Oil*; which being in an over-proportion for an intimate union, rather hinders than promotes vinous Fermentation, but greatly diſpoſes the Subject to putrefaction †.

8. But if the *Salt* predominates, this does not ſo much prevent the ſucceſs of the Fermentation; provided it be in ſome kind of connexion with the oily and earthy *Principles*: But if it be not thus connected, it is readily taken, by ſolution in the Water, from the other duly mixed portion; and thus, in ſome meaſure, promotes and aſſiſts the operation.

9. This equable connexion of Salt, Oil, and Earth into a ſingle compound particle, makes a corpuſcle

* See above §. 2.

† As in Mace, Cloves, Nutmeg, *&c.*

corpuſcle ſoluble in Water; that is, this compound corpuſcle is, by means of its ſaline particle, connected with the aqueous corpuſcles, and moved up and down therewith; that is, become diſſolved therein.

10. Where theſe compound corpuſcles are not thus connected with the Water, many of them join together either into a groſs matter *, or into a looſe, chaffy, or ſpungy one †.

11. When diluted with a little moiſture, theſe compound corpuſcles feel ſlippery, clammy, and unctuous to the touch; and after the like manner affect the taſte with a ropy ſweetneſs or inſipidity ‡.

12. When undiſturbed, or left to themſelves, they preſerve their mutual coheſion, and ſolid or dry conſiſtence, without alteration §.

13. But as ſoon as an *aqueous Fluid* is put to them, there preſently begins a commotion, and afterwards a ſubtile ſeparation among them.

14. This commotion and ſeparation firſt begins in the whole ſubſtance **; for before Water is added, the Subject may remain in dry, ſolid, and large pieces ††; which being reduced to powder, each grain thereof is an aggregate of many leſſer compound corpuſcles; which being put into Water, diſſolve and ſeparately float therein, till at length they become ſo ſmall as to be inviſible, and thicken the conſiſtence of the Liquor.

15. When the compound particles are thus ſeparated from one another, they are next gradually



* As in the Lees of Wine.
† As the Grains in Brewing.
‡ As appears in all Inſtances.
§ Conſider Malt, Raiſins, Sugar, and all the Inſtances.
** As when Sugar diſſolves in Water.
†† As in Malt, Sugar, *&c.*

dually ſeparated from their own different parts that is, the different particles whereof they con ſiſt; *viz.* the Salt, the Oil, and the Earth, ar disjoined from one another, by the interpoſi tion of the particles of Water.

16. The firſt *Commotion* is no more than bare ſolution; when the Water lays hold o the ſaline parts of the compound corpuſcle and thus carries them about with it ſelf: For o theſe ſeveral *Principles* the ſaline one ſooneſt diſ ſolves in Water.

17. But the ſucceeding *Separation*, *viz.* th *fermentative Motion*, is a different thing; as wha diſentangles the oily and earthy parts from th ſaline, partly by the impulſe of the others i their motion, and partly by the force of th aqueous particles that are now continually meet ing and daſhing againſt them.

18. This motion is performed by the *Wate* as a Fluid, or Aggregate of an infinite numbe of particles, in actual and perpetual motion their ſmallneſs being proportionable to that o the fermenting corpuſcles, and their motion, o conſtant ſuſceptibility of motion, by warmth and the motion of the Air, diſpoſing them t move other ſubtile, moveable corpuſcles alſo.

19. But more particularly, an aqueous Fluic gives this *Commotion*, by the certain agreemen of figure and ſize which its particles have wit thoſe of the *Salt* of the fermentable Subject Whence they come to be readily and cloſel applied together, ſo as to move almoſt like on and the ſame compound corpuſcle; whilſt th Water is no way diſpoſed to cohere immediate ly with the *Oil*, or *Earth*. And thus an une qual concuſſion is made in the compound cor puſcles of the Subject; which concuſſion a

length

length ſtriking out the ſaline particle, and looſening the others, brings on a ſeparation of the original connexion of the Subject.

20. Thus if, inſtead of Water, an oily Fluid were poured upon any fermentable Subject, no vinous Fermentation would enſue; as the Oil can neither give a ſufficient impulſe to the compound corpuſcles, which are groſſer than its own conſtituent particles, nor force away the oily or ſaline particles of the Subject from the connexion of the others, which detain, and as it were envelope or defend them from its action.

21. Hence an *aqueous Fluid* alone is the true *Inſtrument* for procuring a fermentable motion to theſe mixed corpuſcles of the Subject.

22. As the ſmall parts of this aqueous Fluid are in a perpetual motion, and by means thereof affect the compound corpuſcles of the Subject, a certain degree of this motion is required, which principally depends upon external heat.

23. 'Tis true, a conſiderable degree of cold will not abſolutely prevent all Fermentation, though 'twill greatly retard it; and a boiling heat will prevent it ſtill more. The due heat therefore for promoting and quickening the operation, is a tepid or middle one, betwixt the two extremes of freezing and boiling.

24. The admiſſion of the Air alſo, though not of abſolute neceſſity, yet greatly promotes and quickens the Action; as being a capital *Inſtrument* in the moving of oily particles, and the true Analyſer of oily Subjects, in concurrence with the motion of Fire *.

25. But whilſt the Air thus contributes to ſtrengthen the effect, it at the ſame time cauſes, by its



* See Lect. II. Exp. III. IV.

its activity, ſome remarkable alterations in th oily part; as being not only capable of movin but abſolutely diſſolving and diſplacing it fro its original connexion; and thus carry it c with it ſelf from the whole Maſs *.

26. And hence, though the conſideration the Air does not ſo properly belong to Ferme tation in the general, yet it does in particular; having an accidental power to alter every ſpeci of this operation: Whence its agency ought be well underſtood, either for procuring alt rations at pleaſure in the fermenting Maſs, for preventing and correcting impendent da gers.

27. The *oily Principle* which the Air thus ſ parates and diſſolves, is alſo elaſtic, though probably has that property from its intercour with the Air it ſelf, added to an extreme ſu tilty of parts; ſo that a ſmall bulk thereof co taining a large number of individual particl may fill and ſatiate a large bulk of Air †.

28. To proceed: When an *aqueous Fluid* added to a fermentable Subject, expoſed to temperate heat, and in ſome ſmall degree to t open Air, a fermentative ſtruggle immediat ariſes; the Water by its continual inteſti motion diſſolving the ſaline part of the compou particles, and carrying them up and down w it ſelf infinite ways, amidſt innumerable otl particles, as well merely aqueous as fermenta ones: Whence, by this colliſion and attriti the oily and earthy particles are at length ſe

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* As may appear by the loſs of Spirit and Flavour in c Fermentations, where the Matter is expoſed to too m Air.

† As in the Atmoſpheres of odoriferous Vegetables; again in Perfumes or ſtrong-ſcented Drugs; as Musk, A bergreaſe, Camphire, Aſſafœtida, &c.

rated and disjoined from their connexion with the saline.

29. The oily particles, as being the most subtile, and most disposed for *elastic motion*, would thus be thrown up to the surface of the Liquor, and carried off by the Air, if they were not long involved or enveloped in the earthy ones; which are not only undisposed and unfit for avolation, but also strongly inclined to form larger collections or aggregations with the earthy ones, and thus sink with them to the bottom *.

30. But before this can fully be brought about, that is, before many of the earthy particles are by degrees collected together upon their frequent meetings with each other, so as to form a bulk that can be no longer moved about by the aqueous Fluid; it happens that, by these repeated collisions, some of the oily particles (now disjoined from the saline ones, which are strongly agitated by the aqueous particles, and separated from the earthy ones) are again, by degrees, more intimately connected with the saline ones: Whilst, on the other hand, these same saline particles imbibe and take to themselves some of the earthy ones; which being left single, upon their separation from the oily particles, floated separately about in the Fluid †.

31. And hence proceed the several different consequences of Fermentation; *viz.* (1) From the extrication of the saline particles of the Subject proceeds the tart, saline, or acid taste of



* In the Form of Lees or Sediment.

† Observe that this whole Doctrine is not delivered as hypothetical, but as derived from a careful Consideration of all the *Instances*, *à priori* and *à posteriori*, both in the way of a just *Induction*.

the Liquor; which is more ſenſible at firſt, before the Liquor is duly compoſed and ſettled or the new arrangement and connexion of the ſaline particles with thoſe of the oily and earthy kinds compleated: After which the Liquor proves milder, ſofter, or leſs pungent. (2) From the oily particles being ſet at liberty, proceeds the ſtrong ſmell of the Liquor, and the head or the ſhining skin upon the ſurface. (3) The earthy particles collecting together in cluſters cauſe the Fluid to appear turbid, and afterward a viſible earthy or clay-like matter to be precipitated: And ſome of theſe earthy parts in their motion arriving at the head or oily skin on the ſurface, cauſe it to thicken; and afterwards taking it down along with them, thus conſtitute the *Lees* which abound in Oil. (4) From this new ſtruggle or colliſion, which is productive both of ſolution and a new connexion in the ſaline and earthy corpuſcles, proceeds the *Ebullition* in Fermentation. And laſtly, by the ſame repeated coalition of the oily with the aqueous and ſaline particles, the *inflammable Spirit* is produced *.

32. *Water* performs this whole ſeries of changes, by becoming the Inſtrument and *Medium* of new ſeparations, tranſpoſitions, and combinations; as alſo preſerving theſe new combinations after they are made, by a kind of conſtant interpoſition, or eſſential concurrence †. For Wine cannot, without extreme alteration, be deprived of all its humidity; though it may of the ſuperfluous part thereof by congelation, without the leaſt prejudice ‡.

33. And

* See Lect. VII. Exp. IV.
† See Lect. XI. Exp. IV.
‡ This appears upon Congelation.

33. And although the aqueous humidity were intirely taken away, yet the fermented matters would ſtill retain and reſpectively ſhew the alterations brought upon them; for the Spirit, with its eſſential aquoſity, would appear in one place, the acid Salt in another, and the dry Earth, or unctuous *Fæces*, in a third *: And in the two laſt the aqueous part may be totally ſeparated, without any way altering the places or ſtate they were put into by the act of Fermentation †.

## Sect. II.

### *Practical Obſervations relating to vinous Fermentation.*

1. According to the Doctrine above delivered, every fermentable Subject is in it ſelf, or may be reduced to, a dry and ſolid body, conſiſting of oily, ſaline, and earthy parts, ſo put together as perfectly to diſſolve with Water into a tranſparent, clammy Liquor: Whence Malt, or other Grain, Grapes, or other Fruit, are to have their proper fermentable parts eſtimated by the quantity of dry, pure, fermentable Matter, or Sugar, they would yield; all their other parts being either chaffy or aqueous, and foreign to the real purpoſe of Fermentation.

2. This teaches us a Rule for reducing all fermentable matters to their leaſt dimenſions, and preſerving them at all times fit and perfect for uſe; *viz.* by making them into pure dry *Sugars:*

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* As we ſee in Tartar, and dry Wine Lees.

† See Lect. VII. *paſſim.*

*Sugars:* Which, though at preſent generally practiſed upon the Sugar-Cane only, is performable to good advantage upon other Subjects *.

3. The perfection of Fermentation in general depends upon three things; *viz.* (1) the goodneſs and ſuitableneſs of the Subject; (2) the goodneſs and proportion of the Water put to it; and (3) the regulation of the Operation.

4. The goodneſs of the Subject in general is determined by its purity and perfect ſolubility in Water, without impairing the tranſparency thereof, or changing its colour. And this character is excellently anſwered by the fineſt Sugar; though its uſual manner of preparation and refinement (by a ſtrong heat) ſomewhat indiſpoſes it for a ready Fermentation, which new expreſſed and unboiled vegetable Juices are greatly diſpoſed to; whence their Fermentation is much ſooner finiſhed.

5. That Water is generally allowed beſt for Fermentation, which of it ſelf contains moſt fermentable parts; and ſuch is, (1) the Water that naturally grows along with Fruits; (2) Rain Water, which is impregnated with vegetable matters; and (3) River Water, which alſo contains ſome vegetable ſubſtances; but (4) Spring Water is the pureſt and leaſt altered by foreign mixture: Whence the trueſt eſtimate might be made of a fermentable Subject by its means, provided it have no peculiarity contrary to the nature of Fermentation †.

6. The quantity or proportion of the Water is limited by the nature of the thing. We ſee that dry fermentable ſubjects will never of themſelves fall into Fermentation; a little moiſture rather

* See Lect. VII. Exp. I. and Lect. X. Exp. III.
† See Lect. V. VII. and X.

rather diſpoſes them to putrify than ferment *; and too large a proportion ſcatters and diffuſes them, ſo that the parts have not their effect upon each other, and become in a manner loſt: So that there is a certain middle proportion, which is beſt; and thus it ſuffers the whole to ferment freely, and obtain ſuch a body and conſiſtence as will enable it to keep ſound and perfect; and this proportion is about two thirds or three fourths of Water to one of perfectly pure and dry fermentable Matter.

7. The regulation of the operation includes, (1) the manner of putting the Subject to work, and (2) the external Regimen during the operation. The Subject may be ſet to work either with or without addition, and with or without heating; and this according to the climate or ſeaſon of the year. The recent expreſſed Juice of Grapes ſeldom requires either; but falls immediately to ferment of it ſelf, and finiſhes the work in a few days. But in cold countries all fermentable Juices require to be quickened by artificial warmth, and the addition of a proper Ferment. The heat ſhould be barely tepid, and the quantity of Ferment moderate; ſo as to begin the operation ſpeedily, before the Liquor receives any damage from the external Air, or change of weather. The Ferment employed muſt be of the ſame nature with the Liquor, or yielded by a fermenting ſubſtance of the ſame kind; otherwiſe it will introduce and impreſs its own foreign nature upon the Subject.

8. *Ferments* are thoſe ſubſtances which added to a Liquor prepared for Fermentation, make it begin and end the operation ſooner than it would have done by it ſelf. They conſiſt of the

* See Lect. VII.

the moſt ſubtile, moveable parts of the fermenting Liquor, already ſeparated from the groſſer or more ſluggiſh; and are therefore thrown up to the top of a fermenting Liquor: Whence being taken in their ſtate of fermenting motion, and added to a freſh parcel of prepared Liquor, no wonder if they ſoon ſet it alſo in a fermenting motion. But care muſt be had not to uſe an over-proportion, leſt inſtead of quickening the operation, it ſhould be perverted by too great a confuſion and diſorder; which if it ſhould thus happen, is not eaſily ſtopped, or its inconveniences prevented.

9. The external Regimen during the operation regards the admiſſion or excluſion of the Air, and the warmth of the place. The free admiſſion of the Air greatly promotes and quickens the operation; but carries away ſome of the fine, volatile, unctuous parts of the ſubject, and thus impoveriſhes the Liquor: So that the moſt perfect way is to exclude the Air, and perform the operation in a cloſe Cask, if expedition be not required. And if a little ſpace be left unpoſſeſſed by the Liquor at the top of the Veſſel, there is no danger of burſting the Veſſel: Though this might otherwiſe be readily prevented, by the uſe of a *Valve*, to let out the foul Air, which is conſtantly generated in Fermentation; and if too long detained in the Cask, is apt to be imbibed again by the Liquor, ſo as to give it a nauſeous taſte and odour. And if the climate or ſeaſon be cold, the place of the operation ſhould be kept moderately warm, by Fire, or ſome proper contrivance; otherwiſe the Fermentation may languiſh, or be checked, before the full effect is procured.

10. Theſe Cautions being duly obſerved, the Operation will be performed to great advantage;

vantage; and when fully ended, or rather a little before, the containing Veſſel muſt be cloſe ſtopped up, and kept well ſecured from the external Air, that the Liquor may, of it ſelf, grow perfectly bright and fine; as it will do, if no error has happened in the management. And this is the moſt perfect method of fermenting Wines, where the fermentable Liquor is prepared by Art*; but other Cautions and Rules are required, when Nature affords the Juice imperfect, or unduly mixed, as in bad Vintages, &c.†

11. But this method of fermenting cloſe is ſomewhat ſlow; and greater expedition is often required in practice; inſomuch as ſometimes to become the primary conſideration. We ſhall therefore next take a view of the ſeveral artificial means to be uſed for ſhortening the operation, without any conſiderable prejudice to the Liquor.

12. The things that have a principal tendency o haſten the buſineſs of Fermentation, are, 1) the making of the Liquor ſufficiently dilute; 2) the addition of a large proportion of Ferment; (3) the keeping the whole in a due degree of warmth; and (4) the free admiſſion of he external Air.

13. 'Tis a common obſervation, that thin Vines finiſh their Fermentation ſooner than ſuch s are rich; as if, for the ſake of diſpatch, they hould be made a little thinner than uſual; the efect may be afterwards ſupplied with Spirit of Vine, and richer Wine, according to the practice in Wine-Countries when the Vintage proves oor and watery‡.

14. A

* See Lect. VII. Exp. I. & Lect. XI. Exp. I.
† See Lect. VII. & XI. *paſſim*.
‡ See Lect. XI. Exp. IV.

14. A large proportion of Ferment has great power to forward the operation, and be comes neceſſary in making all the artificial Wine where the vegetable Juice is not recent, o where it has felt the force of the Fire; unle the Wine be purpoſely deſigned to ferment im perfectly, in order to retain its ſweetneſs, an appear the richer; though this is always with loſs of Strength or Spirit; which, however, ma readily be ſupplied by the help of Brandy.

15. Where the utmoſt expedition is require a due temperature, or tepid degree of extern warmth, muſt, by all means, be kept up b Art, if the Chemiſt or Country does not nat rally afford it: For heat has a peculiar power liquifying and thinning all fermentable Juices, as to make them weak, without leſſening the ſtrength, as diluting does; but rather increaſi it, if not continued too long, or violent.

16. We have already obſerved, that too fr an admiſſion of the external Air, though it grea ly forwards the operation, yet conſiderably pr judices the Liquor, by carrying off its finer a more ſpirituous part. The free Air, therefo is to be admitted prudently, and principally firſt, in order to excite the fermentative motio and this ſpirituous part may be afterwards d tained, or kept from flying off, towards t end of the operation, by cloſe covering the v ſel, or giving but little vent. And when th ſeveral means are prudently uſed together, t operation may be performed with conſidera expedition and advantage; provided the origi fermentable matter be rightly diſpoſed, or d mixed of ſaline or acid, oily and terreſtrial, par

17. The *Phænomena* of vinous Fermentati are various, and differ according to the deg

of the operation; though the ultimate effect is generally the same. Sometimes the Fermentation gives manifest signs of it self; as by frothing, hizzing, explosion, *&c.* and sometimes again scarce any manifest signs at all; whence we may consider it as an *apparent* or *latent operation.* The apparent is sufficiently known by its signs; but the latent has been less regarded.

18. When any fermentable matter is sufficiently diluted with Water, it has immediately a natural tendency to Fermentation; and will often actually ferment and produce a Wine, though a spectator could neither have seen nor well have suspected any fermenting motion in the Liquor. In this case, where no Ferment has been used, and the operation proceeds in its own natural, slow, and silent manner, there may be commonly seen on the surface a thin, polite skin; which, instead of a large, frothy head in the stronger Fermentation, keeps in the fine parts, and prevents their avolation and escape. Sometimes also a degree of hoariness, sinew, or mouldiness, will appear on the top, without mixing it self with the Body of the Liquor, or without communicating any ill taste thereto. And in this manner a slow and silent Fermentation has been carried on for several months, without any spirting up of bubbles, or other common signs of this operation; though it has, at last, finished its course to greater perfection.

19. And something of kin to this *silent Fermentation* remains for a long time in the Liquor, after the common *tumultuary Fermentation* is finished; which indeed leaves its work but imperfect; so that the Liquor afterwards requires a considerable time to grow fine, ripen, and become

come fit for drinking: Whereas in the silen method, these ends are all at once carrying o at the time of the operation. And here lies great part of the advantage which the slow wa of fermenting close has over the common one.

20. 'Tis observable, that though a smal quantity of Liquor finishes its Fermentatio sooner than a large one, yet the larger prove the better; as a great Body of Liquor is not s liable to receive pernicious alterations, fro Heat, Cold, the Air, or other accidental thing And even where nothing remarkable of this ha happened, 'tis surprizing to note the differenc betwixt a small quantity and a large one of th very same Liquor fermented in the very sam manner, only the one in a small and the othe in a large Vessel.

21. Small Wines may be brought to underg a second Fermentation, by being mixed wit proper fermentable materials; and thus ma be rendered stronger and richer, so as to be f for exportation, &c. Otherwise 'tis observe that Wines which finish their Fermentation eight or ten days, will not ordinarily endu the Sea.

22. 'Tis a necessary caution in all Ferment tion, to prevent too great external heat, for fe of changing the Fermentation to Putrefaction and to remove the Wines to a cooler plac when the violence of the operation is over; th they may purge and fine themselves by degree without danger of turning acid, as they are a to do in a hot place. Or if they cannot be ke close, they ought to be early racked from the Lees; which tends to preserve them sound, ar prevents their turning eager, ropy, and foul †.

23. 'T

* See Lect. VII. † See ib.

23. 'Tis to be obſerved of all Liquors prepared by Fermentation, that the interpoſition of *Water* keeps not only the ſaline, oily, and ſpirituous parts, but alſo the mucilaginous and earthy ones, in their due arrangement, and ſome degree of connexion; from which if they are again diſtributed, there happens ſuch a change as cannot well be prevented from proving pernicious; but the Liquor will ſucceſſively and haſtily proceed on to corruption *. Thus if a fermented Liquor be agitated by a great boiling or heat, its proper arrangement is thereby diſordered, and the Liquor not only becomes manifeſtly thick and turbid, but more ſaline and auſtere, through the ſeparation of the ſpirituous and oily particles from the ſaline ones, wherewith, being before in ſome meaſure connected, their Acrimony was ſheathed or abated.

24. Such Liquors tend ſo much the faſter to alteration or putrefaction, if they are not carefully looked after and preſerved; but eſpecially if, through any great commotion by heat, the more intimate connexion of the ſpirituous parts with the ſaline and mucilaginous, or even with the remaining aqueous ones, be diſturbed and broken: Whence either the whole Maſs turns to Vinegar, or a ropy, corrupt, putrid Subſtance †. But if ſuch fermented Liquors are carefully preſerved at reſt, and kept from injuries, they will long remain in a ſound and uncorrupted State; as we continually ſee in Wines and Malt-Liquors.

25. And farther, all theſe fermented Liquors will reſiſt the alterations of the weather, or



* See Lect. VII. † See ib.

ſeaſons of the year, as to heat, cold, and a fermenting humidity in the Air; which is by ſome eſteemed the cauſe of Fretting in Wines; if their ſuperfluous water be artificially ſeparated from them, ſo as that the Liquor itſelf may be concentrated; in which ſtate it will remain for many years unchangeable, through the Summer's heat, and the Winter's cold *.

26. When a chemical Analyſis is made of theſe Liquors, the firſt part that riſes is *inflammable Spirit*; the next, *Phlegm*, mixed with an Acid and an eſſential Oil, leaving a thick Matter, or Rob of Wine, at the bottom; which when freed from its ſuperfluous moiſture, is obſerved to be very durable, and full of Tartar. But the bare mixing of theſe ſeveral parts together will not make the original Liquor again. Which ſhews that they were all before connected in a certain particular manner, which was diſſolved and deſtroyed in the act of ſeparation; and again, that each of theſe productions received a particular new kind of alteration from that act of ſeparation, which will not ſuffer them to reunite as before, without ſome proper intermediate ſubſtance, or a new Fermentation.

27. Hence pure Wine conſiſts of much Water, a moderate quantity of inflammable Spirit, a little eſſential Oil, a proportion of acid Salt, and a certain mixed Subſtance, or *Rob*, called by *Becher*, the *media Subſtantia Vini*. And when theſe ſeveral parts remain firmly united together in their due proportion, the Wine is there in its perfect State: But as their connexion proves looſe, or any one of them becomes deficient, or abounds in an over-proportion, the th

* See Lect. XI. Exp. IV.

the Wine is faulty, and expoſed to injuries and alterations, for the worſe: And this ſhews us the true foundation of what may be called the *Health* or *Diſeaſes* of *Wines*.

28. That a large proportion of Water neceſſarily enters the compoſition of Wine, appears plainly by its artificial preparation *; and again from the congelation of the natural †. But though this large quantity of Water is requiſite in the Fermentation, and ſerves to carry it on the better; yet it is not afterwards eſſential to the Wine, but rather foreign and detrimental; ſo as to expoſe and ſubject it to changes, which it would not otherwiſe undergo: Whence the ſovereign Remedy for all Wines, is to deprive them of their ſuperfluous Water, in order to render them perfect and unchangeable, without ſome uncommon and extraordinary violence or accident. And indeed this Remedy is ſo effectual as to make all others unneceſſary; inſomuch that the pureſt and thinneſt Wines may, by its means, be rendered perfectly durable, and full bodied ‡.

29. But as there may be ſome difficulty in the particular uſe of this grand Remedy (in the large way of Buſineſs) the next Expedient is, to uſe highly rectified and pure Spirit of Wine, in ſuch proportion as to prevent all change for the worſe, and preſerve the eſſential parts of the Wine, as it were by a Balſam. But when the caſe is inveterate, this Remedy of it ſelf will ſcarce prove work ſufficient; unleſs aſſiſted by ſomewhat to give a Body, as that gives Strength. Whence it is highly convenient to have always



* See Lect. VII. Exp. I. † See Lect. XI. Exp. IV.
‡ See ib.

at hand a quantity of Wine made as rich as ever it will ferment; a ſuitable proportion whereof, being added along with the Spirit, will have a very good effect; eſpecially if the whole be quickened with a little *eſſential Oil of Wine*; which, in caſe of over-aqueous Wines, is generally deficient. And this being a capital Diſeaſe in Wines, or that whereto moſt of the reſt are originally owing, it may be proper here to give a Form of a Remedy which has been found effectual for the purpoſe.

30. Take an Ounce of fine eſſential Oil of Wine, mix and grind it with a Pound of dry Loaf-Sugar into an *Elæoſaccharum*; diſſolve this *Elæoſaccharum* in two Gallons of the richeſt Wine; and add to it two Gallons of the fineſt Spirit of Wine, ſo as that they be well incorporated together: The Doſe of this Mixture muſt be proportioned to the Exigence; but in ordinary caſes one half will ſuffice for a Pipe of Wine.

31. There is a Diſeaſe of Wines oppoſite to the former, when their aqueous moiſture is drawn from them too far; whence they become dry, as it were, and parched, for want of it. This caſe indeed cannot well happen, except by the method of Condenſation; whereby Wines may have their eſſential parts brought ſo cloſe together, as to become unfit for drinking till ſet more aſunder, and diluted. But this muſt not be attempted with Water alone, for fear of inducing a flatneſs: The beſt way is, to have a dilute or thin taſteleſs Wine ready at hand for the

the purpose *; whereby any degree of richness may be given at pleasure.

32. But the artificial method of preparing Wines renders all Remedies unnecessary, as it intirely prevents their Diseases; so that they need neither be made too aqueous nor dry, but constantly of a perfect full Body, that shall neither subject them to acidity, ropiness, or foulness, when once well cleared of their gross Lees, in the ordinary way of Racking.

33. But in case the Wine should not speedily grow fine of it self, the addition of a little tartarized Spirit of Wine will hasten the effect †: Or at once to make a general Remedy for Wines that are too poor and aqueous, or such as will not thoroughly fine themselves; let a pure, tasteless, and totally inflammable Spirit be made from Sugar; digest this Spirit upon a tenth part of pure and dry Salt of Tartar for three days; decant the Liquor, and put it to ten times its own quantity of a Wine, made as rich as it possibly would ferment: And then six or eight Quarts thereof will at any time mend, improve, and fine down a Pipe of ordinary Wine.

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* See Lect. VII. Exp. I.
† See Lect. XI. Exp. II. IV.

# LECTURE XII.

## CONTAINING

*Attempts to illuſtrate and improve the Arts depending upon* DISTILLATION; *viz.* Malt-Stilling, Rectifying, *and* Compounding.

*The Subject.*

1. HAving already gone through with the Arts immediately depending upon *vegetable Fermentation*; we next proceed to conſider of the ways of improving the Art of *Diſtillation*; which depends upon Fermentation ſecondarily.

*Diſtillation, what.*

2. The Word *Diſtillation* is here uſed in the popular ſenſe, to ſignify the Art by which all inflammable Spirits, Brandies, Rums, Arracks, and the like, are procured from vegetable Subjects, by the means of a previous Fermentation, and a ſubſequent treatment of the fermented Liquor by the Alembic, or Hot-Still, with its proper Worm and Refrigeratory.

*The Arts herein conſidered.*

3. The Arts therefore at preſent to be conſidered are thoſe of Malt-Stilling, Rectifying, and

and Compounding, with the Business of the Brandy-Merchant, the Officers of Customs and Excise, so far as relates to Spirits, and the several Dealers in Brandies, Rums, Arracks, and Cordial Waters.

4. The Experiments we shall exhibit will shew, (1) the Method of distilling a Spirit from a fermented Malt-Wort, commonly called *Wash*, in order to obtain *Aqua Vitæ*, or the ordinary Malt Spirit; whereof many Cordial Waters are made by the *Compounders*, *Apothecaries*, and others: (2) Our *second* Experiment will exhibit the Method of purifying or rectifying this Spirit, of the first running, or *Low-Wines*, as they are called, into a saleable Proof-Spirit, or what they emphatically call *Proof Goods*; that is, a certain standard Spirit, usually consisting of one half Water, and the other half Alcohol: (3) Our *third* Experiment will exhibit the Art of the rectifying Distiller, or the Method whereby the Proof Goods of the Malt-Stiller are made into a sweeter or cleaner Spirit, for the finer uses of the Compounder and Apothecary: (4) Our *fourth* Experiment will shew the true Method of examining Proof in Spirits; and discover the invalidity of the common methods of judging of the purity, genuineness, and goodness of Brandies, Rums, and Arracks: And (5) our *fifth* and last Experiment, for the present, will shew the Method of making Cordial or Compound Waters in perfection. *Design of the Experiments.*

## EXPERIMENT I.

*The Method of distilling Malt-Wash, or a fermented Mixture of Meal and Malt, for Spirit.*

*The Distillation of Wash.*

5. We now briskly stirred together the Malt-Wash prepared in the last Experiment of our last *Lecture*, and therewith filled two thirds of a Still, first made hot and dewy on the inside with boiling Water, and keeping the whole stirring till it almost begun to boil; then immediately clapped on the Head, and luted it down. There now soon ran, in a slender Stream, from the Nose of the Worm, a spirituous Liquor, that was inflammable, or burnt in the Fire. We continued to work so long as the Liquor that came over would catch Flame when thrown upon the hot Still-Head, when a lighted Candle was applied to the rising Fume.

*Low Wines.*

6. And thus we obtain what the Malt-Stillers call a *Malt Low-Wine*; that is, a spirituous Liquor from fermented Malt and Meal, so diluted with Phlegm, or Water, as that the last Runnings of it would not burn upon the Still-Head. And that which comes over after the Spirit falls off from being Proof, till it will no longer burn in the Still-Head, is called by the Name of *Faints*.

*The Experiment extended.*

7. This Experiment may be rendered general, by a slight variation of circumstances; or made to serve as an instance of all the ways of procuring inflammable Spirits; whether Brandies, Rums, Arracks, Cyder-Spirit, or the like: For if any Wine, Beer, or fermented Liquor

Liquor from Sugar, Treacle, Roots, Fruits, &c. be treated in the same manner, it affords a Spirit differing only according to the nature, or specific taste and odour, of the Subject.

8. But none of these Subjects will afford the least inflammable Spirit without a previous Fermentation*. Thus though the recent Juice of the Grape, or any other fermentable Juice, were distilled to dryness, yet not one drop of inflammable Spirit would be procured: Whence it appears that inflammable Spirit is a thing produced by *Fermentation* †.

9. The Cautions required to render the Experiment successful, and the Production perfect, are, (1) That the Fermentation be well performed, and the Liquor become truly vinous, and of an acid pungency ‡; (2) that it be gently distilled, by means of a soft, well regulated, Fire; (3) that the grosser Oil, apt to rise along with the Spirit, be kept out by a proper Strainer, or thick doubled Flannel, laid under the Nose of the Worm. And if these Cautions be duly observed, the *Low-Wines* will prove considerably pure and vinous. *Cautions.*

10. When all the Spirit is thus obtained, there remains behind in the Still what they commonly call *Bottoms*; that is, the gross parts of the fermented Meal and Malt mixed with Water. The use generally made of this gross matter is for the feeding of Hogs; whence the Malt- *Management.*

* See Lect. VII. Exp. IV.
† See Lect. XI. *passim.*
‡ See Lect. VII. and XI.

Malt-Stillers of *England* are generally large Dealers in Hogs: But in *Holland* that makes a ſeparate Buſineſs.

11. Thus we have gone through three of the principal Branches of Malt-Stilling; *viz.* the Brewing, Fermenting, and firſt Diſtilling parts; or the making of the Wort, the working it in the fermenting Back, and the diſtilling it from the Waſh *. There is but one part more of this Art; *viz.* the Rectifying part; or the way of *making up their Goods*, as they call it, to ſaleable Proof: And how this is performed, will be ſeen by the following Experiment.

## EXPERIMENT II.

*The Method of ſimple Rectification, or diſtilling the Low-Wines, produced by the foregoing Experiment into Proof-Spirit for Sale.*

*Proof-Spirit.*

12. We took the Low-Wines produced in the preceding Experiment, and diſtilled them over again *in Balneo Mariæ*, or barely by the heat of boiling Water; and thus obtained a purer and higher rectified Spirit than before; which being let down with fair Water to a certain ſize or ſtandard called *Proof* †, is what the Malt-Stillers underſtand by Proof-Goods, or *their* rectified Malt-Spirit.

13. The

* See Lect. XI. Exp. VI.

† What this Proof is, ſee explained in the fourth Experiment of the preſent Lecture.

13. The common Malt-Stillers indeed do not ius rectify their Spirit *in Balneo Mariæ*, but arely by rediſtilling their Low Wines in a ſmall- Still; ſo that their Spirit is not ſo clean as at of our preſent Proceſs. The perfection erefore of the Art of diſtilling from Malt ems to require a good method of rectifying ean, as well as careful obſervance of the cau- on above laid down.

14. Having thus regularly gone through the hole Art of the *Malt-Stiller*, as it is practiſed y the more intelligent Artiſts; we proceed to fer a conſideration or two for its farther im- rovement.

15. The Inconveniencies of this Art regard ther the Subject, or the Work: The Subject, e ſee, is Malt; which being of a large bulk, reſpect of its ſaccharine part, and requiring a eat proportion of Water to extract this part; nce many large Veſſels, ſuch as Maſh-Tuns, olers, Fermenting-Backs, Coarſe-Stills, and ne-Stills, become neceſſary therein; whereby e labour alſo is increaſed, and the price of e commodity enhanced. This Art, therefore, ing far removed from ſimplicity, is conſe- ently far removed from perfection. *Inconveniencies.*

16. The Remedy here ſhould ſeem to de- nd upon the introduction of a new Art, ſub- rvient to the Art of the *Malt-Stiller*, and con- ing itſelf to the boiling down of Malt-Wort a Rob*; ſo as to ſupply the Malt-Stiller ith his Subject, in the ſame manner that the *Fine-* *Remedied.*

* See Lect. X. Exp. III.

*Fine-Stiller* is now ſupplied by the Sugar-Bak with Treacle: For thus the compleat buſine of the *Malt-Stiller* might be commodiouſly r duced to a great degree of ſimplicity.

17. By the ſame means the Spirit of t *Malt-Stiller* would alſo become much finer th at preſent; becauſe the Subject would con tolerably refined to his hands, or purged of i groſs, mealy, and husky matter, which yiel a diſagreeable Oil in Diſtillation; and is al apt to burn in the Still, and ſpoil the Spir And we recommend it to thoſe who are skille in this Branch of Diſtillation, to try whether Spirit ſuperior to that of Treacle may not b procured from the *Rob of Malt*, prudently pr pared and fermented.

*Fine-ſtilling.*

18. There needs no particular Experiment t ſhew the buſineſs of the *Fine-Stiller*; this bein no more than working, in the manner abo explained, from a Waſh made by fermentin Treacle with Yeaſt; though it is uſual to add conſiderable proportion of Malt, and ſometime powdered *Jalap*, in the fermenting Back: Th Malt accelerates the Fermentation, and make the Spirit come out the cheaper; and the *Jala* prevents the riſe of any cruſty head on the ſur face of the fermenting Liquor; ſo as to leav a greater opportunity for the free acceſs of th Air; and thus alſo ſhorten the work, by turn ing the foamy into the more hiſſing kind o Fermentation.

EXPERI

## Experiment III.

*The Art of the Rectifier; or the Method whereby the Proof-Goods of the Malt-Stiller are made into a cleaner Spirit, for the finer uses of the Compounder and Apothecary.*

19. To two Gallons of the common Proof-spirit of the Malt-Stiller, procured after the manner of our second Experiment, we added three Ounces of the Black Flux, or a mixture of Tartar and Nitre calcined to blackness *; and drew over all that would run in an uninterrupted stream from the Nose of the Worm, by means of the *Balneum Mariæ*. The Spirit which thus came over, we made up Proof, with fair Water. And the Spirit so prepared is the common saleable *proof Goods* of the rectifying Distiller, when he works to a truth. *Rectification of Spirits.*

20. This is the Spirit we commonly meet with in Trade under the name and notion of *Malt-Spirit*; which is thus fitted for making the common Cordial or compound Waters; being, by Rectification, cleared considerably of its fœtid oil, and nauseous Phlegm. If it be desired still cleaper, one of the best methods is, To dilute the strongest part that comes over first, with a large proportion of fair Water; and draw off the Spirit gently again, by the *Balneum Mariæ*; then making it up proof with fine soft Water. *Malt-Spirit.*

21. But this method will not yet give us the Spirit without some nauseous and disagreeable flavour; nor do the Rectifiers appear acquainted with any good Method for the purpose: They *Inconveniencies.*

* See Lect. II. Exp. II.

They have been labouring after it; but gen
rally in the dark, for want of the proper kno
ledge of the Facts and Experiments neceſſary
the Enquiry. Thus, for inſtance, they ſee
little apprehenſive that it is the Oil of the Ma
reſiding in the Spirit, which cauſes them all th
trouble; or that it is the eſſential Oil of t
Subject which gives to Malt-Spirits, Brandi
Rums, and Arracks their particular Flavou
For if the eſſential Oil could be totally ſeparat
from Malt-Spirit, that Spirit might be render
flavourleſs and taſteleſs; and then any oth
Flavour might, by means of other eſſential Oi
be introduced into it; whereby it might
made to reſemble either *French* Brandy, Ru
or Arrack. And in the effecting of this, wi
ſimplicity and cheapneſs, the perfection of t
Art of Rectifying ſeems to conſiſt.

*Remedied.* 22. We would recommend to them the w
of working from a Spirit largely diluted wi
Water into Water again; whereby the eſſenti
Oil would, at one operation, be doubly ſep
rated. But we have no great hopes that a
direction of this kind can prove ſerviceable
them, for want of their being acquainted wi
chemical Operations, and the beſt contrivanc
and large ways of diſtilling with elegance a
ſimplicity.

23. The Chemiſts, however, have help
them to a tolerable Expedient for covering t
imperfections of the Spirit which they cann
cleanſe; *viz.* by the addition of what is call
*Spiritus Nitri dulcis*; a ſmall proportion where
will give an agreeable Vinoſity to a Hogſhe
of Spirit. But this Expedient is attended wi
an inconvenience; for the Flavour is very a
to fly off, or be loſt, when the Spirit is kept
a Cask: But the ſucceſs proves different, wh

he Spirit is kept, well ſtopped down, in a Glaſs.

24. The Art of the *Rectifier* might entirely be *Improve-*
et aſide as uſeleſs, if the original *Malt-Stiller* *ments.*
ould make his Spirit perfect at a ſecond opera-
ion; as we judge it might be made. But here
gain, the *Malt-Stiller* can ſcarce be brought to
orſake the beaten track. If they are diſpoſed
o improve their Art, we would recommend to
hem, *firſt*, the brewing in perfection; and *ſe-*
*ndly*, the keeping of their Waſh, after the
anner of ſtale Beer, till it has entirely loſt its
Malt Flavour, and acquired a pungent, acid,
inoſity; and then, *thirdly*, leaving out the
ees, to diſtil with a well-regulated Fire. Thoſe
ho have not tried, would ſcarce conceive how
greeable a Spirit may be thus procured from
Malt, at the very firſt Diſtillation. The gain-
l part of the Secret depends upon *an artificial*
*Method of making Malt-Liquors expeditiouſly ſtale,*
*ight, and flavourleſs, though otherwiſe vinous* *.

## Experiment IV.

*he Method of examining Proof in Spirits; and*
*detecting the Invalidity of the common Ways of*
*judging of the Purity, Genuineneſs, and Goodneſs*
*of Brandies, Rums, and Arracks.*

25. We took a long Vial, half filled with *Proof taken*
e common Proof-Spirit of the *Malt-Stiller*, *of Spirits.*
d giving it a ſmart ſtroak with its bottom
ainſt the Palm of the Hand, there appeared
the ſurface of the Liquor a Chaplet, or
own of Bubbles; which went off, or diſap-
ared, in a certain ſtrong manner; that is, firſt
remain-

* See *Appendix* to Lect. XI. See alſo Lect. VII.

remaining a while, and then going away, b degrees, without breaking into ſmaller Bubble or riſing into larger. And when the Bubbl go off, in this manner, the Spirit is ſaid to b proof, or merchantable *.

*Erroneous.* 26. And by this kind of Proof, all Diſtiller Brandy-Merchants, Brokers, and the Office of the Cuſtoms and Exciſe, judge of the Streng and Quality of Brandies and Spirits, in all th Brandy-Countries and Sea-Port Towns of *Eu rope*; whence it is alſo conveyed to other par of the World. It may therefore appear ſtrang here to oppoſe the general opinion and practic in a particular where the intereſt of ſo mar trading people, watchful againſt all impoſitio is concerned: And yet we undertake to ſhe that this kind of Proof is a mere fallacy and d ception; for if but a little vinous or ſaccharin Matter, as Treacle, Syrup, Muſt, the Rob Fruits, *&c.* be added to a quantity of high rectified Spirit of Wine, this ſlight addition w give a Brandy-Proof to that Spirit; whic therefore, by this trial, may be made to pa for Brandy; that is, a compoſition of half Wat and half Alcohol; whereas in reality is is almo totally Alcohol.

*Detection.* 27. The fraud is eaſily detected; not in th common way practiſed upon the *Keys*, but b burning a little of the Spirit in a Spoon; fo thus it will leave the ſaccharine Matter, in dry form, behind.

*Sophiſtication.* 28. Whether there be any Method com monly known, of making any ſpirituou Liquor of *Europe*, that contains muc leſs than a half of Alcohol to paſs curre for Proof-Spirit, is not ſo certain: Bu doubtle

* See Lect. VII. Exp. IV. § 36, 37.

doubtleſs this might be eaſily effected; for we ſee that Arrack is Proof; or affords a ſtrong Crown of Bubbles, upon ſhaking, as well as Brandy; tho' Arrack uſually contains not above half the Quantity of Alcohol that Brandy does; and if but a Drop or two of its own or any other eſſential Oil be added to a Pint of Proof-Brandy, this is ſufficient to deſtroy its Proof, and make it appear much weaker than it is.

*Diſcovery.*

30. To prevent being impoſed upon in this Way, we might have Recourſe to the *Eſſay-Inſtrument*, or *Hydroſtatical Balance:* A Gallon of Alcohol is computed to weigh ſeven Pounds and a half, and a Gallon of Water, eight Pounds; whence the compound Gravity of an equal Mixture of the two may be aſſigned. But it is a more ſure and ready Method, to burn a little meaſured Quantity of the Brandy to be tried, in a cylindrical metalline Veſſel, plunged in cold Water to an equal Height with the Brandy, and when it ceaſes to burn, exactly meaſuring the Remainder, which is the Water. But if the Spirit has loſt one half of its Meaſure by burning, the Brandy may be allowed Proof; if more or leſs, it muſt be judged of accordingly*.

*Eſſay Liquors.*

31. But beſides the falſe Method of judging the Strength of Brandies by what is called Proof, there is another no leſs fallacious one of judging of their Goodneſs; tho' kept a great Secret in few Hands, as a thing ſome Dealers imagine a certain Criterion for determining whether foreign Brandies are mixed with Corn Spirits. Theſe Dealers are provided with a certain *yellow Liquor*, a few Drops whereof being poured

*Its Uſe.*



* See a Paper of M. *Geoffrey*, to this Purpoſe, in the *French* Memoirs.

into a Glaſs of right *French* Brandy, gives it beautiful blue Colour; by the Strength an Brightneſs of which Colour they judge of th Genuineneſs, or unmixed State of the Commo dity; and buy upon this kind of Proof: When they may come to be much deceived; for if a ordinary Malt Spirit was to be coloured wi Oak, this Spirit would ſuſtain the preſent M thod of Proof; and might therefore be purch ſed by theſe Dealers for *French* Brandy.

*How made.* 32. This Proof-Tincture, or *Eſſay-Liqu* may be expeditiouſly prepared, by diſſolving little green Vitriol (firſt calcined to Redneſs) a weak Spirit of Sea-Salt; which thus becom a *yellow Liquor*; a ſingle Drop or two where being added to a Glaſs of any inflammable Sp rit coloured yellow or brown with Oak, w inſtantly turn it of a beautiful bright Blu Whence it is evident that this kind of Trial no more than a Fallacy, and only ſhews wh Brandies are tinged with Oak; as they conſtan ly are by lying long in the Cask. And that is the Oak which thus cauſes *French* Brandies turn blue with the *Eſſay-Liquor*, appears ag from hence; That if the beſt and oldeſt *Fre* Brandy be re-diſtilled, and thus made colourle it will not turn blue with the *Eſſay-Liquor*; cauſe all the Tincture of the Oak, or ting Matter of the Cask, is left behind in the Sti

*Its Fallacy detected.* 33. One of the beſt Methods to prevent be impoſed upon by the mixing of Malt Sp with a finer, is to acquire a Habit of judg by the Taſte and Smell; for Malt Spirit is u ally rectified ſo ill, by the Addition of fi alkaline Salts, or certain flavouring Ingredie that it may commonly be perceived by the N or Palate; eſpecially if the Brandy propoſed Examination be largely diluted with Water,

prev

prevent its over-heating the Mouth; or elſe be burnt in a Spoon, ſo as to leave the Phlegm to be taſted and ſmelt by itſelf: For this Phlegm, if the Brandy were debaſed by a Corn Spirit, will taſte and ſmell conſiderably nauſeous, very different from the Phlegm of pure *French* Brandy.

## Experiment V.

### *The beſt Method of making Cordial or Compound Waters.*

34. We infuſed a Pound of freſh Citron-peel in two Gallons of good Melaſſes Spirit; then committing the whole to the Still, drew off the Spirit gently, with Care to avoid the *Faints*: Then making up, as they call it, with ſoft Water, ſo as to leave the Liquor-Proof, we added half a Pound of Fine Sugar; and thus procured a genuine *Citron Water*. *Citron Water prepared.*

35. This Experiment is general, and ſhews the uſual Methods of making all the Compound Cordial Waters, by thoſe Diſtillers who are called Compounders, and alſo by Apothecaries; tho' Apothecaries ſeldom make diſtilled Waters as good as the Compounders. *The Experiment extended.*

36. The Perfection of this Branch of Diſtillation depends upon the Obſervance of a few Rules, which might be eaſily complied with: and theſe Rules we ſhall here lay down, as judging them of Conſequence to the Improvement not only of the Art of the Compounder, but alſo of a Branch of Pharmacy and Medicine. *Compound Diſtillation improved.*

37. The firſt Rule is, *To uſe a well-cleanſed Spirit, that is freed from its own eſſential Oil.* For the Deſign of Compound Diſtillation is to impregnate the Spirit employed with the eſſential *Rules.*

Oil of the Ingredients, it ought firſt to hav
depoſited its own.

38. The ſecond Rule is, *To ſuit the Time* (
*previous Digeſtion to the Tenacity of the Ingredient*
*or the Ponderoſity of their Oil.* Thus Rhodium
Wood and Cinnamon require to be longer d
geſted before they are diſtilled than *Calami*
*Aromaticus*, or Lemon-Peel. Sometimes alſo C
*hobation* (that is, the pouring of the Spirit onc
drawn off, back upon the ſame Ingredients
proves neceſſary; as particularly in making th
ſtrong Cinnamon Water; where the eſſenti
Oil is extremely ponderous, and difficultly riſ
along with the Spirit, without one Cohobatio
more.

39. The third Rule is, *To ſuit the Fire*
*Strength of the Diſtillation to the Ponderoſity of t*
*Oil intended to be raiſed with the Spirit.* Thu
ſtrong Cinnamon Water ſhould be diſtilled
briſker than the Spirit of Mint or Baulm.

40. The fourth Rule is, *That a due Propo*
*tion of only the finer eſſential Oil of the Ingredients*
*thoroughly united or incorporated with the Spirit;*
*as to keep out the groſſer and leſs fragrant Oil.* An
this may be chiefly effected by leaving out th
*Faints*, and making up to ſtrong Proof with fi
ſoft Water in their ſtead. And upon the Ob
ſervance of theſe four eaſy Rules the Perfectio
of the Art of Compound Diſtillation ſeems
depend.

41. The Addition of fine Sugar to Cordi
Waters is a thing of leſs moment, and may b
uſed or omitted occaſionally. And if theſe D
rections be obſerved, there will be no need
fining down Cordial Waters with Allum, Whi
of Eggs, Iſing-Glaſs, or the like; for they w
be preſently bright, ſweet and pleaſant taſte
without any farther Trouble.

42. An

42. And thus we hope to have ſhewn the Way of perfecting the Art of Compound Diſtillation; even by the common Alembic, or hot Still, without the Uſe of the *Balneum Mariæ*; for which there is here no Occaſion, if the Artiſt be but expert in working by the Alembic.

## AXIOMS and CANONS.

1. We learn from our preſent Enquiry, that inflammable Spirits are the Creatures of vinous Fermentation; or that they are actually produced, tho' not ſeparated, in that Operation *.

2. That the Action of Fermentation produces ſuch a Change in the Waſh, as to render it ſeparable by the Fire into ſeveral Portions of Matter, beſides the inflammable Spirit, ſpecifically different from what the Liquor would have afforded by the ſame Treatment before Fermentation †.

3. That at different Times of Diſtillation there comes over a Liquor of different Properties; *viz.* firſt, an extremely acrid, aromatic, and biting one; which goes off by degrees, and ends in Acidity **.

4. That the Art of *Malt-Stilling* may be conſiderably improved; (1) by reducing the brewing and fermenting Parts to one Operation; (2) by diſtilling ſlow; and (3) by keeping out the groſs Oil of the Subject.

5. That this Art may be farther improved, by fermenting a clear, well-brewed Wort, and keeping it to be ſtale, or till it has loſt all Fla-



† See Exp. I.

‡ See Lect. VII. Exp. IV. See alſo *Appendix* to Lect. XI.

* See Exp. I. and *Appendix* to Lect. XI.

vour of the Malt; as it will naturally do by long lying, or in a very ſhort time by the Help of a certain artificial Treatment *.

6. That the Perfection of the Art of *Malt-Stilling* requires the Aſſiſtance of a new Art, to produce a kind of Treacle from Malt, or the Reduction of the Art of the *Malt-Stiller* to the ſame Simplicity as that of the Fine-Stiller †.

7. That the eſſential Oil of the vegetable Subject is the Thing which gives to all Spirits their particular Odours and Flavours ‡.

8. That the fineſt, moſt ſubtil and efficacious Part of this eſſential Oil always riſes firſt in Diſtillation **.

9. That the Purity and Perfection of Spirits, conſidered merely as Spirits, greatly depend upon their being cleanſed firſt of their eſſential Oil, eſpecially its groſſer Part, and next of the Phlegm ††.

10. That Brandies are a Mixture of one half Water, and the other half Alcohol; that the Meaſure of the Strength of Brandies is the Quantity of Alcohol they contain; and therefore that their Water may be commodiouſly left behind upon Exportation or Carriage ‡‡.

11. That as Brandies hold ſome ſmall Proportion of eſſential Oil, they are in Strictneſs dilute *Quinteſſences* *; whence their Properties and Effects may be eaſily explained, in a chemical manner.

12. That

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* See Exp. I. and III.
† See Exp. I. and III.
‡ See Exp. I. III. V.
** Exp. I. III. V.
†† Exp. I. II. III. V.
‡‡ Exp. I. II. III. IV.
* Exp. I. II. III. V.

12. That the Perfection of Rectification in Spirits depends upon finding out a ſimple Method of ſeparating all the Oil and Water from a Spirit*.

13. That the great Affinity betwixt the eſſential Oil and Spirit is the phyſical Cauſe of the Difficulty found in the Rectification of Brandies†.

14. That the Perfection of the Art of *Malt-Stilling*, whereby a Spirit might be procured pure at the firſt Operation, would ſuperſede the Art of Rectifying ‡.

15. That the Bubble-Brandy Proof may be artificially given to high-rectified Spirit of Wine, and as eaſily deſtroyed in Proof-Spirit, without weakening the Spirit**.

16. That the common Methods of trying and examining Brandies by the Bubble-Proof, and their turning blue with a vitriolic Solution, are abſolutely fallacious, and not to be truſted for the Purpoſes intended ††.

17. That *phyſical Proof* in Brandies is the Property they have, upon ſhaking, to generate a Crown of moderately large Bubbles on their Surface, by means of a certain Tenacity, ariſing from a ſtated Proportion of eſſential Oil diſſolved in among them; which Tenacity may alſo be given by other Bodies *.

18. That a ſure Method of determining the Strength of Brandies is by Deflagration, or burning away their Alcohol; then examining the



* See Exp. III.
† Exp. I. II. III. V.
‡ Exp. III.
** Exp. III. IV.
†† Exp. IV.
* Exp. IV.

remaining Phlegm by Weight or Measure, and comparing it with the Weight or Measure of the Alcohol *.

19. That erroneous Notions, or inaccurate and false Methods of Trial, may prevail, and become almost universal in Trade; so that even the prudent Merchant shall buy and sell upon weak Trials, whilst the Detection, Rectification, or Adjustment thereof, belongs to some other Branch of Knowledge †.

20. That the Way of perfecting the Art of Compound Distillation is, (1) To procure a well-cleansed Spirit; (2) To use proper Digestion; (3) To distil brisk, or slow, as the Subject requires; and (4) To keep out the Faints, or gross Part of the essential Oil of the Ingredients **.

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* Exp. IV.
† Exp. IV.
** Exp. V.

# LECTURE XIII.

CONTAINING

*The Ways of procuring Vegetable* Oils, *and* Salts; *with their Uſes in ſeveral* Arts *and* Trades.

## I.

1. WE now proceed to illuſtrate and improve the common Methods of procuring and employing vegetable *Oils* and *Salts*; whereon the Exerciſe of various Arts and Trades depends. *The Subject.*

2. The Parts of Vegetables that chiefly abound with Oil are, the Seed, the Leaves, the Fruit, and the Bark. Thus the Seed of Muſtard, and of the Sun-Flower, Almonds, Nuts, Beech-Maſt, *&c.* afford a copious Oil by Expreſſion; and the Leaves of Roſemary, Mint, Rue, Wormwood, Thyme, Sage, *&c.* the Berries of Juniper, Olives, *Indian* Cloves, Nutmeg, Mace, *&c.* the Bark of Cinnamon, Saſſafras, and Clove yield a conſiderable Proportion of eſſential Oil by Diſtillation *. *The oily Parts of Vegetables.*

3. And much in the ſame manner is Oil or Fat contained in the Parts of Animals; being either interſperſed among the muſcular Fleſh, collected into particular Bags or Cells, or lodged in the Cavities of the Bones, *&c.*

4. Our

* See below Exp. II.

*The Design of the Experiments.* 4. Our first Experiment will shew the Method of procuring Oils by Expression, from Nuts, Seeds, Mast, Olives, *&c.* The second will exhibit the Method of procuring those called the Essential Oils of Vegetables. The third Experiment will shew the Method of rectifying those called the Empyreumatical Oils. Our fourth Experiment will shew the Method of refining Sugar. The fifth Experiment will shew the Way of refining *Tartar*: Our sixth, the Manner of refining *Nitre*, or Salt-Petre; and our seventh and last Experiment, for the present, will shew the Method of making Pot-Ash.

## EXPERIMENT I.

### *The Method of procuring Oil by Expression, from Nuts, Seeds, Mast, &c.*

*Expressed Oil of Almonds.* 5. We took two Pounds of Sweet Almonds, blanched, and beat small in a Stone Mortar; then wrapping the Mass up in a Piece of strong and thick Canvas, we committed it to a strong Skrew-Press; where being squeezed betwixt two cold Iron Cheeks, it gradually parted with a considerable Quantity of Oil.

*The Experiment extended.* 6. This Experiment holds of all those vegetable Matters that contain a copious Oil, in a loose manner, or in certain Cavities or Receptacles; the Sides whereof being broke, or squeezed, makes them let go the Oil they contained. And thus the Zest, or Oil of Lemon-Peel, Orange-Peel, Citron-Peel, *&c.* may be readily obtained by Pressure, without the Use of Fire; for the Rinds of those Fruits being pressed green, the oily Parts will separate from the aqueous,

aqueous, and may be rendered pure by waſhing them in fair Water*.

7. How far this Method of obtaining Oils may be applied to Advantage, ſeems not hitherto conſidered: It has been commonly applied to Olives, Almonds, Linſeed, Rape-Seed, Beech-Maſt, Ben-Nuts, Wallnuts, Bay-Berries, Mace, Nutmeg, *&c.* but not that we know of to Juniper-Berries, Cachou-Nuts, *Indian* Cloves, Pine-Apples, or Fir-Nuts, and many other Subjects that might be enumerated, both of Foreign and Domeſtic Growth. It has however been of late applied to Muſtard-Seed, with great Succeſs; ſo as to extract a curious yellow, or golden-coloured Oil from that Seed; and at the ſame time leaving a Cake behind fit for making the common Table-Muſtard.

8. Certain dry Matters may, as well as moiſt ones, be made to afford Oils by Expreſſion; for when they are not ſo moiſt as Almonds, or fit to be reduced to a Pulp in a Stone Mortar, they may be ground into a Meal; which, being ſuſpended to receive the Vapour of boiling Water, will thus be moiſtened ſo as to afford an Oil, in the ſame manner as Almonds; eſpecially if the Iron Cheeks employed be firſt heated, by lying in boiling Water. And thus an Oil may be procured from Linſeed, Hemp-Seed, Lettuce-Seed, White-Poppy-Seed, *&c.*

9. The Oils obtained by this Treatment, ſhould be ſuffered to depurate themſelves by ſtanding, in a moderately cool Place, to ſeparate from their Water, and depoſite their Fæces; from both which they ought to be carefully freed. And if in this manner they are not rendered *Regulated.*

* See below § 9.

rendered sufficiently pure, they may be well washed and beat with fresh Water; then thoroughly separated from it again, by the Separating-Glass; whereby they will be rendered bright and clean.

10. Particular Care must be had to keep such of these Oils cool as are designed for eating, or for any internal Use; because they are apt in a few Days time to turn rancid and corrosive with the Heat of the Summer's Sun, so as to prove very unwholsome. Hence the Physician and Apothecary should be cautious that the Oils given in Pleurisies, and other Distempers, be fresh drawn from sound Subjects, no way tainted, or already turned rancid; as Almonds, Pistachio's, and other Nuts, are apt to do: And again, that these Oils have felt no considerable Heat, either in the drawing, or by standing long in a warm Place. And the same Caution should likewise extend to animal Oils and Fats, intended both for internal and external Use; since these also become rancid, or change to yellow, red, or grey Colour in hot Weather; and thus become exceedingly nauseous and corrosive; as we see in Butter, Bacon, and other fat Bodies; which then prove only fit for the Tallow-Chandler, or other ignoble Uses.

*Applied to other Subjects.*

11. Our present Experiment is likewise applicable to the procuring of Oils or Fats from certain animal Subjects; for the Membranes, skinny and stringy Parts of animal Bodies which contain much Fat, being chopped small, and set in a Pan over the Fire, become fit for the Canvas-Bag; and by Pressure afford a large Quantity of Fat; as we see in the Art of Chandlery; which thus extracting the oily Matter,

er, leaves a hard Cake, or what they commonly call *Graves*, behind.

12. Theſe *Graves*, and all the Reſiduums of the preſent Proceſs, after being ſqueezed ever ſo hard with the Preſs, will ſtill afford a copious Oil by boiling in Water; ſo that it might perhaps be more profitable for the *Tallow-Chandler* to boil his *Graves* for Oil, as Bones are uſually boiled for it, than to diſpoſe of them in the ordinary manner. And it is ſurprizing to obſerve, what a large Proportion of Oil theſe dry, and to Appearance almoſt exhauſted Bodies, will yield, by repeated boiling in Water, but particularly by being committed to the *Digeſtor**.

13. So likewiſe if the Almonds remaining in the Canvas, after the Expreſſion of their Oil, be ground in a Mortar with warm Water, the Water will thus extract their remaining Oil, and turn therewith into a milky Liquor, or *Emulſion*. And if this Operation had been performed upon the Almonds at firſt, before we committed them to the Preſs, we might thus have diſſolved out all their Oil, and left only a dry, chaffy, or light, husky, and exhauſted Matter behind. Whence we have a Method of diſſolving Oils in Water; and thereby of making a kind of artificial Milk; which, by ſtanding, will afford a Cream, and turn ſour, like the Milk of Animals; but not grow rancid with Heat, like Oil. Whence ſuch Emulſions may, in ſome Caſes, be medicinally uſed with greater Safety and Succeſs than expreſſed Oils. *Farther Uſes.*

14. Any of theſe expreſſed Oils will receive particular Colours and Odours at the Diſcretion of the Artiſt. Thus for Example: If a little *Oils coloured.*

* See Lect. VI. Exp. VII.

little *Alkanet-Root* be barely infused in Oil-Olive, it gives a beautiful red Colour to that Oil, without altering its Taste. So again; If a few Drops of the essential Oil of Cinnamon be added to a Pint of Sallad-Oil, such Sallad-Oil may be rendered agreeable to those who admire the Flavour of Cinnamon. And thus may Oil, Butter, *&c.* be diversified infinite ways, by a proper Use of tinging Ingredients, and suitable chemical Oils.

*Essences.* 15. The same Contrivance has likewise its Uses in making Essences for the Service of the *Perfumer*; not only where essential Oils are procurable, but also where these either cannot well be obtained, or only in small Quantity. The essential Oil of Jasmin Flowers, Honey-Suckles, Sweet Briar, Damask Roses, Lilies of the Valley, *&c.* are either extremely dear, or scarce obtainable by Distillation; and in some of them the odorous Matter is so subtil as almost to be lost in the Operation. But if Jasmin Flowers, Damask Roses, Lilies of the Valley, *&c.* be barely infused in fine Oil of Nuts, or Oil of Ben, drawn without Heat, and kept in a cool Place, the subtil odorous Matter of the Flowers will thus pass into the Oil, and richly impregnate it with their native odoriferous Spirit; which can scarce otherwise be procured, or separated from the Flowers, without Loss, or Debasement. And these Essences may be rendered perfect by straining off the Oil at first put on, and letting it stand again, without Heat, upon fresh Flowers; thus repeating this Operation twice or thrice.

*What they are.* 16. To consider the Thing attentively; We shall find that the Essences thus obtained are a kind of *essential Oils*, not greatly differing from those prepared by Distillation from the Flowers, Seeds,

Seeds, or Barks of odoriferous Vegetables; for all ſuch *eſſential Oils* are found to be little more than the native odorous Spirits of the vegetable Subject, wrapped up, lodged, or entangled in an unctuous or direct oily Subſtance. This oily Subſtance indeed riſes, or becomes vegetable, by the Heat of boiling Water; but ſo do not the Oils gained by Expreſſion*: Whence the principal Difference betwixt thoſe natural, and *artificial eſſential Oils*, as we may call them, ſeems to conſiſt in the different Tenacity, Volatility, or Fixedneſs of their unctuous or direct oily Parts; the *native Spirit* appearing the ſame in both; tho' indeed it is the more delicate and unimpaired in the artificial kind of eſſential Oils, as not having here felt the Force of Fire. And hence perhaps ſome conſiderable Improvements might be made in the Art of the *Oilman*, *Perfumer*, and *Apothecary*; not to mention other oeconomical Uſes and the Art of the *Dairy*.

## Experiment II.

### *The Method of procuring the eſſential Oils of Vegetables by Diſtillation with Water.*

17. We took eight Pounds of Juniper Berries, and bruiſing them in a Stone Mortar; directly put them into a Still, along with four Gallons of River-Water; and working with a brisk Fire, we drew off a Gallon of Water; and thus obtained along with it a conſiderable Proportion of a fragrant eſſential Oil, which we ſepa- *Eſſential Oil of Juniper diſtilled.*

* See Exp. II. hereafter.

ſeparated from the Water by a Separating-Glaſs.

*The Experiment extended.* 18. This Experiment is eaſily rendered general, or made applicable to the diſtilling of the eſſential Oils from Flowers, Leaves, Barks, Roots, Woods, Gums, and Balſams, with a ſlight Alteration of Circumſtances; as by longer Digeſtion, briſker Diſtillation, *&c.* according to the Tenacity and Hardneſs of the Subject, the Ponderoſity of its Oil, *&c.**

*Uſes.* 19. If the Liquor that remains in the Still, after the preſent Operation, be ſtrained, and evaporated to the Conſiſtence of Honey; it makes the *Rob of Juniper-Berries*, which is eſteemed a valuable Medicine; that may defray the Charge of the Operation, being uſed as a Strengthener of the Stomach and Inteſtines, as a Preſervative from the Stone and Dropſy, and as a Cure for the Diſorders of the urinary Paſſages.

*Eſſential Oils claſſed.* 20. Eſſential Oils may be divided into two Claſſes, according to their different ſpecific Gravities; ſome floating upon Water, and others readily ſinking to the bottom thereof. Thus the eſſential Oil of Cloves, Cinnamon, and Saffafras readily ſink; but the Oil of Lavender, Marjoram, Mint, *&c.* ſwim in Water. The lighteſt of theſe eſſential Oils is, perhaps, Oil of Citron-Peel, which even floats on Spirit of Wine; and the heavieſt ſeems to be Oil of Saſſafras: But the ſpecific Gravities of the intermediate eſſential Oils are not hitherto adjuſted and *tabled*, as for the Service of Chemiſtry they ought to be. †

21. For

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* See Lect. XII. Exp. V.

† See below § 29.

21. For obtaining the full Quantity of the more ponderous Oils from Cinnamon, Cloves, Saſſafras, &c. it is proper (1) to reduce the Subjects to fine Powder; (2) to digeſt this Powder for ſome Days in a warm Place with thrice its Quantity of ſoft River Water, made very ſaline by the Addition of Sea Salt, or ſharp with Oil of Vitriol; (3) to uſe the ſtrained Decoction, or Liquor left behind in the Still, inſtead of common Water, for a freſh Digeſtion; (4) to uſe for the ſame purpoſe the Water of the ſecond Running, after being cleared of its Oil; (5) not to diſtil too large a Quantity of theſe Subjects at once; (6) to leave a conſiderable part of the Still, or about one fourth, empty; (7) to uſe a brisk Fire, or a ſtrong boiling Heat, at the firſt; but to ſlacken it a little afterwards; (8) to have a low Still-Head, with a proper internal Ledge and Current, leading to the Noſe of the Worm; and (9) to cohobate the Water, or pour back the Liquor of the ſecond Running upon the Matter in the Still; and repeating this once or twice. *How obtained to Advantage.*

22. Theſe Cautions are all neceſſary, in order to diſtil the ponderous eſſential Oils to Profit and Perfection. The phyſical Reaſons whereon they depend may deſerve to be conſidered. (1) The Reduction of the Subject to Powder, expoſes all its Parts the better to the Action of the Water and Salt; whereby the Oil is the more mollified, attenuated, and rendered fitter to riſe along with the aqueous Vapour in Diſtillation. (2) The Digeſtion is requiſite for the ſame Reaſon; as being no more than allowing Time for this Action to be performed, in a moderate Warmth. The Water ſhould rather be the ſoft Water of Rivers, than that of Rain, which is more corruptive or fermentative; or *Reaſons of the Cautions.*

than of Springs, which is often hard, ſo as not to mollify the Oil, but rather defend it from the Action of the Salt, or Acid; which are added not only to prevent all Tendency to Fermentation or Corruption, that would abſolutely change or deſtroy the Oil; but more particularly, as having a known Property of attenuating, liquifying, diſſolving, and purifying groſs, viſcous, and tenacious Oils. Beſides which, it likewiſe increaſes the ſpecific Gravity of the Water; whereby the Subject is now buoyed up, ſo that it cannot readily touch the Bottom of the Still, or come in the way of the Fire to be ſcorched: And at the ſame time this Addition alſo increaſes the Heat of the Liquor, or makes it exceed that of mere boiling Water; whence the Aſcent of the Oil is likewiſe promoted. (3) The ſtrained Decoction is properly uſed inſtead of Water, as being already ſaturated with oily Particles; ſo that it cannot much rob the Subject. And (4) the ſame holds alſo of the Water of the ſecond Running; which neceſſarily contains ſome oily Particles. (5) If too large a Quantity of the Subject be diſtilled at once the Heat will neceſſarily act unequally, or ſtrong upon ſome Parts, and weak upon others whence, as the Oil is ſo extremely ponderous a large part of it will be left behind in the Subject. (6) If too much empty Space be left in the Still, it will be difficult for the ponderous Oil to aſcend; and if too intenſe a Heat be uſed, it deſtroys the grateful Odour of the Oil, without raiſing any conſiderable Quantity; and if the Still be filled too full, the Matter will be apt to boil over, and foul the Oil. (7) The Fire is ordered to be brisk at firſt, to prevent the Oil, now in ſome meaſure ſeparated by the Heat, from going back into the Subject.

But after a part is thus come over, if the Fire be not a little ſlackened, the Oil is apt to ſcorch, and come out at the Noſe of the Worm in the Form of a Smoke, that cannot be catched and condenſed; yet the whole Operation need not be long continued, or above two Hours, becauſe the valuable part of the Oil ſoon comes over. (8) If the Head of the Still be not low, the ponderous Oil will have too far to riſe; and unleſs the Oil be directed to the Worm by a proper Ledge and Current, a conſiderable part will fall back into the Still, and ſo prolong the Operation, or leſſen the Yield. (9) Laſtly, Two or three Cohobations, or Returns of the Water upon the Subject in the Still, muſt needs bring over all the Oil that will any way riſe. And Water already ſomewhat impregnated with the Oil, is manifeſtly better for the Purpoſe than ſuch as has never been uſed before.

23. The Directions here laid down for obtaining the ponderous eſſential Oils to Advantage, are eaſily transferred to the obtaining of the lighter: So that we need not dwell particularly upon them.

24. Many of theſe *eſſential Oils* being coſtly things, it is common to adulterate or debaſe them ſeveral ways, ſo as to render them cheaper both to the Seller and Buyer. Theſe ſeveral ways ſeem reducible to three general Kinds; each whereof has its Method of Detection: For as in *Logic* every Sophiſm has its Redargution; ſo in *Chemiſtry* every Fallacy may be diſcovered. *Eſſential Oils adulterated.*

25. Eſſential Oils are adulterated, (1) with expreſſed Oils, (2) with Alcohol, and (3) with cheaper eſſential Oils.

26. (1) If any eſſential Oil be adulterated with an expreſſed Oil, this is eaſily diſcovered, by adding a little Alcohol to a few Drops of the *The Fraud diſcoverable.*

ſuſpected eſſential Oil, and ſhaking them together; for the Alcohol will thus diſſolve all the Oil that is truly eſſential, or gained by Diſtillation, but leave the expreſſed Oil untouched; whereby the Compound of the two is ſeparated, ſo as that their Quantities may be judged of, or the Proportion of the Debaſement found: For by adding Water to the Alcohol, which had taken up the eſſential Oil, the Water will unite with the Alcohol, and leave the eſſential Oil ſeparable in its own Form.

27. (2) If any eſſential Oil be adulterated with Alcohol, as it may be in any Proportion up to that of an equal Quantity, without being eaſily diſcoverable either by the Smell or Taſte the way of Deduction is, To let a few Drops o the ſuſpected Oil fall into a Glaſs of fair Wa ter; for if Alcohol be mixed with the Oil, th Water will immediately turn milky; which i would not do if the Oil was pure. And by con tinuing to ſhake the Glaſs, the whole Quantit of Alcohol employed in the Adulteration wi be drunk up by the Water, and leave the O undiſſolved behind.

28. (3) The third Method above mentione of adulterating the richer chemical Oils, is b mixing them with the cheaper eſſential kind: ſuch in particular as the Oil of Pine-Woo Oil of Turpentine, &c. And this is frequen ly practiſed, by putting Fir-Wood, Turpentin or Oil of Turpentine, into the Still, along wi the Herbs, ſuppoſe Roſemary, Lavender, O ganum, &c. in the ſame manner as Diſtille add common Malt Spirit in the diſtilling of Wi Lees. And by this means the Yield of an C may be conſiderably increaſed. But the O thus adulterated will diſcover themſelves time, by the want of their natural Flavou

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which is overpowered by that of the Turpentine, *&c.* But the quicker Detection is, To drench a Piece of Paper, or a Linen Rag, in the ſuſpected Oil, and hold the Paper or Rag before a gentle Fire; for thus the grateful Odour of the Plant will ſoon fly off, and leave the Smell of Turpentine, *&c.* in its room.

29. But if this way of adulterating eſſential Oils be practiſed in Perfection, it ſeems ſcarce diſcoverable, unleſs the *Table of the ſpecific Gravities of eſſential Oils*, above recommended *, were ready at hand: For it is known to ſome few, that *Balſam Capivi* yields a large Proportion of eſſential Oil by Diſtillation with Water, even to the Quantity of five or ſix Ounces from a Pound; and that this Oil is much ſweeter than any of thoſe before mentioned, as uſed for Adulteration: Whence it is eaſy, by diſtilling any the aromatic Vegetables along with this Balſam, or by mixing their Oils with the Oil of *Balſam Capivi*, to debaſe them largely, without being greatly ſubject to Diſcovery, except by the more philoſophical Chemiſts, who underſtand the Uſes of the *Hydroſtatical Balance*. But it ſhould be obſerved, whether, by long keeping, the chemical Oils thus adulterated with the Oil of *Balſam Capivi*, will not diſcharge the Ink of the written Label, faſtened to the Containing-Glaſs, as eſſential Oils adulterated with Oil of Turpentine, or other terebinthinaceous Oil, are found to do, on account of the acid Vapour that continually exhales from ſuch adulterated Oils.

30. The Methods already laid down for detecting the Sophiſtications commonly practiſed in *eſſential Oils*, are general; beſides which



* See § 20.

ſome Oils have Methods peculiar to themſelves. Thus the eſſential Oil of Camomile Flowers may be certainly known to be adulterated with Copper, and Oil of Turpentine, *&c.* if it retains its native blue Colour above a Year. The eſſential Oil of Rue, if genuine, remains fluid in the Cold, and if adulterated, congeals. And every Sect of this kind, of which there are many already known, ſhould be duly collected: For it is certainly of great Importance to Medicine, that the genuine eſſential Oils of Vegetables ſhould be well diſtinguiſhed from the adulterated, becauſe capable of producing extremely different Effects in the Body; a thing little regarded by the fraudulent Adulterator.

## EXPERIMENT III.

### *A Method of rectifying Empyreumatic Oils.*

*Empyreumatic Oil ſweetened.*

31. It was obſervable in our dry Diſtillations of Wood *, Wormwood †, and Bone ||, *&c.* that there always came over a groſs, fætid, empyreumatic Oil, of a nauſeous and diſagreeable Colour, and abominable Taſte. To rectify this Oil, we took two Pounds thereof, and waſhed it well by the repeated Effuſion of hot Water, and ſtirring them well together; till at length the Water came away conſiderably pure; whereby the Oil was rendered leſs nauſeous both to the Smell and Taſte: Then ſetting it in an open Veſſel over the Fire, that it might diſcharge the Water lodged therein by the Waſhing, we afterwards put it into a Glaſs Retort, and drew it over in a Sand Heat; whereby it left a black, fæculent,

* See Lect. II. Exp. III. † See Lect. VIII. Exp. I.
|| See Lect. VIII. Exp. II.

fæculent, or burnt, crusty Matter behind, and became more fluid, sweet, and mild.

32. If the Distillation be repeated ten or twelve times, either in a fresh Retort every time, or in the same, the Oil being constantly returned upon its own *Fæces*, or *Caput mortuum*; these *Fæces* will every time increase in Quantity, so as to leave the Oil purer and thinner, till at length it becomes almost as thin and fluid as Oil of Turpentine, or Spirit of Wine; being extremely volatile, transparent, and penetrating; but still of a hot, pungent Taste, and a somewhat faint and disagreeable Odour. *The Experiment carried farther.*

33. This Oil, obtained from an animal Subject, particularly from Blood, has been lately used in *England*, as a Remedy for the Epilepsy, Gout, and other obstinate Diseases, under the Name of *Oleum animale*. It was many Years since used for the same Purposes in *Germany**. But doubtless it should not be given too freely as an Internal: But, as an external Medicine, it may be of Service, in resolving hard Tumours, removing fixed Pains, *&c.* for it is extremely penetrating and discutient. And on this Account it might, perhaps, be used to Advantage in several Arts that require a highly subtilized Oil. *Uses.*

34. But it being chargeable to bring the gross empyreumatic Oils to this Degree of Purity and Subtilty, many chemical Operators continue to throw them away as useless; and the rather, because of that intolerably nauseous Smell and Taste with which they affect all things that they touch, or come in the way of. But as large Quantities of these Oils are necessarily obtained in the Distillation of Harts-Horn, Blood, *&c.*



* See *Hoffman. Observat. Physico-Chym.* p. 58, 59.

it may be worth trying, whether they cannot be purified in a cheaper manner than above deſcribed: For Example; By drawing them over from Pot-Aſh; or, what is ſtill more profitable, by digeſting them therewith; ſo as at length to turn, by the Mixture, by Sublimation, into a volatile, alkaline Salt, as good as that of Harts-Horn, Blood, putrified Urine, *&c.*

And thus much for the Subject of vegetable Oils. We next proceed to vegetable Salts.

## II.

### EXPERIMENT IV.

*The Method of refining Sugar; or bringing the ſweet Juice of the Sugar-Cane into a white, dry, and ſolid Subſtance.*

*Sugar refined.*

35. We took ſix Pounds of coarſe or black Sugar, as it comes unrefined from the Sugar-Colonies, and diſſolving it, over the Fire, in an equal Quantity of ſtrong Lime-Water, we added the Whites of four Eggs, whisked up into a Froth, and ſtirred the whole well together, in order to clarify the Sugar, after the ſame manner as Syrups are uſually clarified; we then boiled the Liquor to a higher Conſiſtence than that of a Syrup, or till it would ſhoot grainy in the Cold. To make it do this the better, we continued to add Lime-Water at ſeveral times in the boiling. And having obtained this Point of Conſiſtence, called by the Sugar-Refiners, *Proof*, we poured the whole into a Sugar-Baker's Earthen Mould, ſtopping the Hole in the lower end; then ſetting the Mould in a moderately warm Place, the Sugar, after ſome Days, *ſet* hard, or hardened; then we opened the lower Orifice

Orifice of the Mould, and inverted the ſharp End into a little Pot, or *Sugar-Baker's Receiver*; and now applied to the wider End, or on the Top of the Sugar, a Mixture of Tobacco-Pipe Clay and Water, made into a kind, thin, pappy Subſtance. And thus the Water quitting the Clay, ſoaked through the Sugar, without diſſolving the grained Part, and carried down with it only the treacly Matter, lodged betwixt the Stores of the Sugar; which treacly Matter was catched by the Receiver underneath. And thus, by keeping the Clay frequently wetting, and ſometimes renewing it, all the Treacle was got out, and a pure Loaf of White Sugar left behind; which we afterwards dried in a warm Chamber, and kept it in a dry Place.

*The Proceſs and Rationale.*

36. The chemical Hiſtory of Sugar deſerves to be traced through all its Stages. The ripe Sugar-Canes are ground down in a Mill betwixt Iron Rollers, kept continually feeding; ſo that the expreſſed Juice runs, in a Stream, into its proper Receiver; from whence it is ſoon committed to the firſt boiling Pan, to prevent its turning eager; where it is boiled, ſcummed, and cleared of its groſſer and lighter Feculencies that float a-top; and alſo drawn from its heavier *Fæces* which fall to the Bottom. And thus the Juice is brought to a kind of *Mellago*, or *Rob* *: For the Juice of the Sugar-Cane, when firſt boiled down, is like the Rob of Malt, Raiſins, the boiled Juice of the Birch or Sycamore-Tree, *&c.* and would never appear in the ſaline Form of a Sugar, without ſome Contrivance to ſeparate its herbaceous, fæculent Part, and a particular Addition to give it a conſiſtent Form. Both which Ends are anſwered by the Addition of

* See Lect. X. Exp. III.

of Lime-Water: For the Rob of the Sugar-Can being of an acid and unctuous Nature, th Quicklime deſtroys the prevalent Acidity, diſ ſolves and ſeparates the groſſer unctuous Mat ter; and at the ſame time, combining alon with the truly ſaccharine Part, gives a ſolid an dry Conſiſtence. And ſomething of this Effec Lime-Water has in every freſh Boiling; ſ that by a prudent Uſe hereof the Sugar may at repeated Operations, or by boiling it ove again with more or ſtronger Lime-Water, b brought almoſt to a cryſtalline Form. And o the Strength, Goodneſs, and Quantity of th fine Part of the Lime, thus introduced into Su gar, depends the Hardneſs, Whiteneſs, an ſhining, rocky Reſplendency of Loaf-Sugar. S that the Perfection of the Refiner's Art depend in a great meaſure upon the prudent Choice o his Lime, and the Management of Lime-Wa ter.

37. The treacly Matter ſeparated from th Sugar, is collected together and boiled, ſcum med, and treated with Lime-Water again, t obtain all the Sugar from it that it will afford in a dry Form: And when no more can be pro cured from it by the Sugar-Baker, it is the called *Treacle*; being before uſually terme *Syrup*; which it perfectly reſembles: Inſomuch that a thorough Knowledge of the Art o preparing *Syrups*, with the Effects of thei different Conſiſtences, and their Diſpoſitions t ferment, turn acid, or candy, and the bad way of clarifying them, *&c.* may contribute to im prove the Art of Sugars: And accordingly i appears, that moſt of the Improvements in th Refining of Sugars have been owing to Apothe caries and Chemiſts.

38. Sugar

38. Sugar, thus refined, and diſcharged of its ſuperfluous oily Parts, is thus rendered dry, or thirſty, or apt to imbibe aqueous Moiſture, or Oil; upon which Property depends that *Uſes.* uſeful Invention of *Elæoſaccharums*, occaſionally mentioned above *; whereby we are furniſhed with a very advantageous Method of uniting Oils with Waters, Wines, Spirits, or all manner of aqueous, vinous, or ſpirituous Liquors; whereby ſuch Liquors may be altered in their Flavours, and improved in their Virtues, at pleaſure: For, by grinding a ſmall Proportion of any eſſential Oil with dry Loaf-Sugar, the Oil is thus rendered miſcible with any of the above mentioned Liquors; and at the ſame time no way impaired, but rather improved, in its Efficacy.

39. And thus we are taught an extemporaneous Method of making all theſe ſimple and compound Waters, whoſe Virtues depend upon the eſſential Oils they contain: Which is the Caſe of moſt ſimple Waters; as thoſe of Mint, Pennyroyal, *&c.* Nay, ſome ſimple Waters may be procured in greater Perfection by this means than by Diſtillation, as it is commonly performed. Thus the ſimple Water of Baulm, for Inſtance, may be made better by means of the *Elæoſaccharum of Baulm* and pure Water, than by ſimple Diſtillation; which in this Caſe brings over but little of the eſſential Oil.

40. And for compound Waters, they may be thus made to greater Perfection than we uſually meet with them: For if only the firſt part of the eſſential Oils that comes over be ground with the Sugar, and introduced into a very clean Spirit, the Cordial Waters ſo prepared will be no

* See Lect. XI. Exp. I.

no way inferior to those distilled in the ordinary manner. And thus Cinnamon-Water, Clove-Water, Nutmeg-Water, Citron-Water, &c. which depend upon the Use but of one Ingredient, may be readily made. And if compound Waters are required from several Ingredients, we need only have a compound *Elæosaccharum* at hand.

41. These *Elæosaccharums* also, as they are easily made, either simple or compound, in great Variety, might help to improve the Art of Cookery, as affording the Virtues of Aromatics in a commodious Form, for several oeconomical Occasions; and may thus be carried the longest Voyages without danger of spoiling, or of having their Virtues impaired; which the natural Spices, though ever so well cured, are liable to.

42. Again; A proper Set of these Elæosaccharums might afford a Variety of serviceable Medicines, that shall have all the Qualities required in the best Medicines; *viz.* be at once simple, parable, efficacious, and pleasant: For essential Oils, containing the specific Virtues of the Subjects, or those which constitute every Plant the thing it is, these Oils are some of the most concentrated, powerful, restorative, and reviving Medicines hitherto known.

## EXPERIMENT V.

### *The Way of Refining Tartar.*

*Tartar refined.*

43. We took two Pounds of common White Tartar, reduced to Powder, and put to it five Gallons of fair Water, in an earthen Pan; and setting it over the Fire to boil, we in the mean time beat up the Whites of two or three Eggs and

and whisked them in among the Liquor; which we afterwards skimmed and ſtrained; then ſet it to ſhoot in an earthen Veſſel, in a cool Place, for two Days; at the Expiration whereof we found a parcel of whitiſh Cryſtals ſticking to the Sides of the Veſſel.

44. This is a very troubleſome and imperfect Operation; for Tartar requiring twenty times its own Quantity of Water to diſſolve it, the Veſſels, the Fire, and the whole Apparatus, muſt of neceſſity be large to refine a ſmall Quantity of this Salt; which yet is not ſufficiently refined at one Operation, though the Whites of the Eggs take up much dirty, and light earthy Matters, as the more ponderous ſink to the bottom upon ſtanding. Hence the Operation requires to be ſeveral times repeated, before the Cryſtals will become perfectly white; which they would ſcarce ever do, if the Veſſel wherein the Operation is performed were metalline; and Veſſels of Earth, which this Salt does not corrode, being hard to procure, ſo large as they are required for the purpoſe, this adds to the Inconvenience. *Inconveniencies.*

45. It is true, for moſt Uſes in Chemiſtry, unrefined Tartar will anſwer as well as the refined; but for the Service of certain Arts, particularly Dying, it is required thoroughly purified: So that a more commodious Method of refining it ſhould be endeavoured after; whereby at leaſt we might be able to refine it in *England*, as well as they do in *France*. *Remedied.*

46. Tartar is of a very particular Nature; being a ſolid and firm vegetable Salt, extremely hard to diſſolve in Water, as containing much earthy and unctuous Matters, which defend it from the Action of Water: Whence we are directed to ſoften often the Body of this Salt, or looſen

looſen its Texture, in order to its more commodious Refinement. And this End may be obtained by a prudent Uſe of Lime-Water, or a weak Lixivium of Pot-Aſh, or Salt of Tartar, as in the making of *tartarized Tartar* *; wherein common Tartar is united with its own fixed Salt, and rendered eaſily ſoluble in a ſmall Proportion of Water. But there needs not be ſo much Alkali uſed for this purpoſe, as to deſtroy the Acidity of the Tartar; and if too much ſhould happen to be added, it may be mortified with Oil of Vitriol, ſo as not to prejudice the Salt.

*The Experiment perfected.*

47. But where an extremely pure and perfect Cream or Cryſtal of Tartar is required, we recommend the ordinary Cryſtals or Cream of Tartar, to be diſſolved in Water, made highly acid with rectified Oil of Vitriol; for if the ſuperfluous Humidity be afterwards exhaled, the Tartar will thus ſhoot into perfectly tranſparent and beautiful Cryſtals, without at all participating of the Oil of Vitriol. And by the help of theſe Directions common Tartar may be refined in great Perfection, and with no leſs Trouble than the more ſoluble vegetable Salts.

*Uſes.*

48. When the powdered Cryſtals of Tartar are mixed with half their Weight of Salt of Tartar, and diſſolved together in boiling Water, they make a very extraordinary neutral Liquor or *Menſtruum*; and by Evaporation a neutral Salt, of very uncommon Properties. This Salt eaſily runs in a moiſt Air; and will powerfully aſſiſt in extracting the reſinous or oleaginous Parts of Vegetables, by being boiled with them in Water. The aqueous Solution of this Salt will diſſolve the tough Bodies even of *Myrrh*,

* See below § 47.

*Myrrh, Gum Lac*, &c. and is much better fitted than Salt of Tartar for many of the ſame Purpoſes where that Salt is commonly employed. This neutral Salt, or tartarized Tartar, is excellent in healing Wounds, and cleanſing Ulcers: it is an agreeable and ſucceſsful Purgative in Hypochondriacal Caſes; and, diſſolved in Water, makes a pleaſant kind of *Purging Waters*. Its Virtues and Powers, both as a Menſtruum and a Medicine, ſeem not hitherto ſufficiently known; whence we recommend it over to farther Experience.

## Experiment VI.

### *The Method of Refining Nitre, or Salt-Petre.*

49. We diſſolved four Pounds of rough Nitre, as it comes to us from the *Indies*, by boiling it in as much Water as would commodiouſly ſuffice for that Purpoſe; then ſet it to ſhoot for two or three Days in a covered Veſſel of Earth, with Sticks laid acroſs for the Cryſtals to adhere to. Theſe Cryſtals being afterwards taken out, were drained and dried in the open Air. *Nitre refined.*

50. This ſeems to be the beſt and ſimpleſt Method of purifying Nitre; for thus, by its own natural Property of cryſtallizing, it ſhoots pure from the Sea-Salt, or other Foulneſs that is apt to mix among it. However, if the Nitre prove unctuous, it may be proper to add a little Lixivia of Pot-Aſh, Lime-Water, or Allum. And if by this means it does not become ſufficiently pure for making the beſt Gunpowder, or *Aqua Fortis*, it muſt be diſſolved again, and recryſtallized, in the manner of our preſent Experiment; which being repeated, with a larger Proportion of Water than before, a ſlow Evapora-

poration, and by ſuffering the Salt to ſhoot
a moderately warm Place, without the free A
miſſion of the external Air, the Nitre will
obtained in its utmoſt Purity and Perfection.
is judged to be pure, when, being thrown up
live Wood Coals, it fulminates briſk, and w
make perfect Gunpowder and *Aqua Fortis.*

*Hiſtory of Nitre.*

51. The chemical Hiſtory of Nitre is ſtill d
fective. This Hiſtory ſhould ſhew by wh
means Nitre is procurable from all animal a
moſt vegetable Matters: For there are ma
Experiments and Obſervations, which appe
to prove, that Nitre originally proceeds fr
putrified Vegetables; that many uncorrupt
vegetable Subjects contain it in a large Propo
tion; and that all animal Subjects contain
*ſemivolatile Nitre*; which may be rendered mo
fixed, or like the common, by the Addition
Pot-Aſh or Quicklime *.

52. To thoſe diſpoſed to enter upon this u
ful Enquiry, we recommend a full Knowled
of the Methods now in uſe for procuring Nit
from certain Earths that are dunged by A
mals, and putrified Vegetables; the ſhort
ways of ſeparating the unctuous Matter fr
the Nitre, which occaſions all the Difficult
and a due Compariſon of the Proceſs for pr
curing and refining of Nitre with that for pr
curing and refining of Sugar. There is Rea
to believe, an Enquiry of this kind might be
tended with ſuch Succeſs; as to ſhew that Ni
is not peculiar to any one Country, but obta
able in Plenty wherever animal and vegeta
Subjects abound †.

EXPER

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* See Mr. *Lemery*'s Papers upon the Subject in the *Fr*
Memoirs. See alſo Dr. *Stub*'s *Legends no Hiſtories.*

† See *Glauber*'s *Proſperity of Germany.*

## EXPERIMENT VII.

### *The Method of making Pot-Aſh.*

53. Having burnt a Quantity of common Billet-Wood to grey Aſhes, we took ſeveral Pounds of theſe Aſhes and boiled them in Water, ſo as to make a very ſtrong *Lixivium*, or *Lie*. This Lie we ſtrained thro' a coarſe Linen Cloth, to keep out any black Parts of the half-burnt Wood that might happen to remain in the Aſhes; then we directly evaporated this ſtrained Lie in an Iron Pan over a quick Fire, almoſt to Drineſs; we now took out the Matter remaining at the bottom, and putting it into an Iron Crucible, ſet it in a ſtrong Fire till the Matter melted; and then immediately poured it out upon an Iron Plate; where it ſoon cooled, and appeared in the Form of a ſolid Lump of Pot-Aſh. *Pot-Aſh prepared.*

54. And much after this manner is Pot-Aſh made in the large way of Buſineſs, for the Service of the Soap-Boiler, Glaſs-Maker, Fuller, *&c.* But according to the difference of the Wood, or combuſtible Matter employed, with the manner of burning it, and conducting the Proceſs, different kinds of Pot-Aſh are prepared. *Uſe.*

55. There are certain ſaline Plants that yield this Pot-Aſh to great Advantage, as particularly the Plant *Kali*; there are others that afford it in leſs Plenty, and of an inferior Quality, as Bean-Stalks, *&c.* But in general, all vegetable Subjects afford it of one kind or other, and may moſt of them be made to yield it tolerably perfect, after the manner of our preſent Experiment; even the Loppings, Roots, and *And Application.*

refuse Parts of ordinary Trees, Vine-Clippings &c.

*Difference.* 56. But besides the Difference found in different Vegetables for producing this Salt, as some may naturally contain more or less of the saline oily, or earthy Principles, than others *; another Difference will arise from the manner of burning the Subject, according as this is done with a greater or less degree of Fire, or access sion of the Air. If a vegetable Subject be burnt in a close, stifling manner, to a grey, or somewhat blackish or brown Ashes, these Ashes thus containing more of the Oil of the Subject, will afford a more unctuous Salt, that easily melts in the Fire, and is better fitted for the ready making of Soap. But if the Subject be burnt in the open Air, which has every way free access thereto, the Ashes will be white, or contain no part of the Oil of the Subject; and thus the Salt will difficultly melt in the Fire, and prove fitter for the making of Glass (where no Oil is required) than of Soap.

57. A third Difference in Pot-Ash arises from the length or shortness of Time it is detained in the melting Fire; whereby it becomes either of a grey, white, bluish, or greenish Colour; grey or white if it be soon taken out; and bluish or greenish if long detained therein. And according to these Differences Pot-Ash is more or less sharp or strong; a longer continuance in the Fire always consuming the more unctuous parts and leaving the saline ones more naked; provided no considerable proportion of Earth remain mixed with the Salt, which in that case would soon be vitrified, or turn to Glass, and have no saline property at all.

58. The

* See Lect. VIII. *passim.*

58. The fixed Salts of all Vegetables, when reduced to abſolute Purity, or entirely ſeparated from the other Principles, appear to be one and the ſame thing; at leaſt not manifeſtly to differ *. Whence it ſhould ſeem that, by a ſuitable Management, good ſaleable Pot-Aſh might be made in all Places where vegetable Matters abound: For if, by examining *Ruſſia* Pot-Aſh, for Example, we find, that its ſuperior Excellence depends upon its being clear of Earth, or upon its containing a large proportion of Oil, or fixed Salt; theſe Advantages may, by properly regulating the Operation, be given to *Engliſh* Pot-Aſhes, ſo as perhaps to render the latter as good as the former. But where the Pot-Aſh of any remarkably ſaline Vegetable is to be imitated, as that of *Kali* ſuppoſe, we would recommend a prudent ſprinkling of the Subject with Salt or Sea Water in the burning. And by theſe ways properly diverſified, any Principle that is naturally wanting in the Subject might be artificially introduced, ſo as to perfect the Art of Pot-Aſh; whereon the Art of Soap-making depends. *Improvement.*

59 For to make Soap requires an intimate Union of the Salt of Pot-Aſh with Oil, or any Vegetable or animal Fat. This Union in the preſent Method of Soap-making is procured by tedious Operation, or by long boiling a weak Lie of Pot-Aſh and Quicklime with the Fat; adding a ſtronger and a weaker Lie occaſionally by degrees, till the requiſite Point to the Perfection of the Soap is hit. *Uſes in the Art of Soap.*

60. It might greatly contribute to ſhorten this Operation, and eaſe the Expence thereof, if a Mechanical Motion or Engine were employed inſtead of Fire, to procure this intimate Union of *Improvement in that Art.*



* See Lect. VIII.

the Lie and Oil. And that ſomething of thi kind is practicable, appears from hence; Tha if, for Example, half a Pint of the Soap-boiler' ſtrongeſt, or *Capital Lie*, as they call it, b briskly ſhook in a Vial, with an Ounce o more of Oil-Olive, for half a quarter of a Hour, and then the Vial be ſuffered to reſt there will, in a ſhort time after, be found ſolid Cake of tolerable Soap at the top of th Liquor; and may be eaſily preſerved in tha form by breaking the Vial, and rendered harde by being expoſed to the Air.

*Hiſtory of Soap.*

61. We could wiſh that the *Chemical Hiſto* of Soap were extant; for it ſhould ſeem tha many Advantages might be thence derived particular Arts and Trades. This Hiſtory is thing of larger extent than will be generally a prehended, as containing three large Branche (1) the *Hiſtory of Pot-Aſh*; (2) the *Hiſtory of O and Fats*; and (3) the *ſeveral Ways of uniti them to Advantage.*

62. (1) The *Hiſtory of Pot-Aſh* would ſh wherein the Superiority of the foreign Aſh particularly thoſe of *Marſeilles*, *Caſtile*, *Veni* and *Joppa*, conſiſts; why the Soaps at preſe made in *England* fall ſhort of Perfection; a poſſibly inform us of the Ways whereby ev *Joppa* Soap might be equalled in *England*. F ſuch a Hiſtory would trace out the real phyſi Differences betwixt one ſort of Pot-Aſh a another; with the Ways of converting any o of them into the reſt*; ſo as to fit them for t Soap-boiler, Glaſs-maker, *&c.* reſpectively: would ſhew how the mildeſt Pot-Aſh is obta able, for the more curious Soaps; and eſpecia for thoſe intended to be uſed medicinally, &

A

* See above §. 62—65.

And, by the way, there is room to ſuſpect that a thorough Enquiry into this Subject would ſhew the Matter of all Pot-Aſh to be the Matter of Nitre; or that all the Vegetables which yield Pot-Aſh by *Calcination*, might be brought to afford Nitre by *Putrefaction*; or that Pot-Aſh is nearly the ſame thing, both in Nature and Subſtance, with *fixed Nitre* *.

63. (2) The *Hiſtory of Oils and Fats* would alſo ſhew how one ſort might be converted into another, or hard animal Fats into liquid Oils, and liquid Oils into ſolid Fats, by digeſting Oils with certain coagulating Acids, *&c.* how all the foreign ſolid Oil-Soaps might be imitated in *England*; and how a great variety of *liquid Soaps* might be prepared for many different purpoſes; the Foundation of the Thing entirely depending upon the Uſe of a highly ſubtilized, and thin *vegetable Oil.*

64. (3) The *Hiſtory of uniting fixed vegetable Salts with Oils*, might deſcribe ſeveral Machines for the purpoſe; whereby many Tuns of Soap ſhould be readily made by means of Mills, wrought by the Wind or Water; and this either with or without Fire. It might alſo inform us of ſeveral *Menſtruums*, or *connecting Mediums*, which ſhould, either alone, or with little Aſſtance, procure an intimate Union. And that ſomething of this kind is practicable, we are aſſured by particular Experiments.

## AXIOMS and CANONS.

1. We learn from the foregoing Enquiries, that large Quantities of Oil may lie concealed



* See *Glauber's Proſperity of* Germany; and M. *Lemery's* Papers upon *Nitre* in the *French* Memoirs.

in apparently dry Bodies; where neither th Eye, nor any of the Senſes, can perceive th ordinary Signs of Oil *.

2. That Oils gained by Expreſſion are apt t turn rancid, and become unwholſome, by Heat Whence they ſhould always be kept cool, an not be drawn by the means of Fire, if intende for curious or internal Uſe †.

3. That much Oil may be ſeparated by boi ing Water from the Subjects that have felt th utmoſt force of the Preſs: Whence an ey ſhould be had upon the Cakes of Linſeed, Mu ſtard-Seed, *&c.* for obtaining a farther Oi after they have been once ſqueezed ‡.

4. That the oily Subſtance of Nuts, Almond and the like vegetable Subjects, is ſoluble Water, by bare Triture, into a vegetable Mil having a great affinity with the Milk of An mals ||.

5. That *expreſſed Oils* may be readily change or improved, in their Colours, Taſtes, an Odours; ſo as that any one of them may affo a great variety of apparently different kinds **.

6. That aromatic Vegetables yield an *eſſenti Oil* by Diſtillation with Water; which Oil co tains the eſſential or ſpecific Taſte, Smell, an Virtues of the Subject ††.

7. That the *native Spirits*, or fine odorifero parts of Vegetables, are readily imbibed, a long preſerved, by expreſſed vegetable Oils ‡‡.

8. That the difference betwixt the *artific and natural eſſential Oils of Vegetables*, depen upon the different fixedneſs or volatility of th direct unctuous parts *: Whence we are dire ed to a way of introducing the *native Spirits*

Pla

* Exp. I. † ib. ‡ ib. || ib. ** ib. †† Exp. ‡‡ Exp. I. * Exp. II.

Plants into finer or lighter Oils than the common expressed kind; so as perfectly to imitate, or exceed, the natural essential Oils.

9. That there are sure Methods of discovering several fraudulent and abusive kinds of Adulteration in *essential Oils*; but that a more curious Adulteration is practicable, so as to elude the common Trials *.

10. That every *essential Oil* has its determinate specific Gravity: Whence, if a Table of their specific Gravities were formed, from a known genuine Sett, such a Table might be of service in detecting the Frauds or Debasements frequently practised in these Oils †.

11. That several Cautions are required to extract the *essential Oils* of aromatic *Indian* Vegetables, to advantage; which Cautions being duly observed, such Oils may be obtained in *England*, perhaps as perfect as in the *Indies* ‡.

12. That a highly attenuated Oil is, by repeated Rectifications, obtainable from the gross, fætid, and empyreumatic Oil of vegetable and animal Subjects **.

13. That the gross, empyreumatic, *animal Oils* may, by digestion with fixed Alkalies, afford volatile Salts ††.

14. That the Matter of *Sugar* is, originally, a vegetable Juice, apt to grow sour with Heat; and by bare boiling not reducible to solid Sugar, but only to a mellaginous or treacly Substance ‡‡.

15. That many other vegetable Juices, as particularly those of the Birch and Sycamore-Trees, the Rob of Malt, Raisins, *&c.* are convertible into good Sugars, by the same means that are used in the ordinary Sugar-making *.



* Exp. II. † ib. ‡ ib. ** Exp. III. †† ib. ‡‡ Exp. IV. * ib.

16. That the Art of refining Sugar, ſo as t make it rocky, perfectly white, ſpangly an reſplendent, principally depends upon a pruden choice and uſe of Lime-Water *.

17. That refined Sugar renders *eſſential Oil* inſtantaneouſly miſcible with Wines, Water and Spirits; ſo as to afford a ready means o improving ſeveral Arts †: Or that the prope Introduction, Uſe, and Application of *Elæoſac charums*, may improve the Art of Diſtilling Pharmacy, Wines, Cookery, and Medicine ‡.

18. That the troubleſome Art of *refining Tar tar* may be ſhortened and improved by the uſ of Alkalies and Oil of Vitriol **.

19. That Tartar is convertible into a ver different Salt, by being united with its ow fixed Salt; ſo as hence to become a powerfu Menſtruum, and a valuable Medicine ††.

20. That the Cryſtallization, once or twic repeated, is a ſure Method of refining Nitre or *Salt-Petre* *.

21. That Nitre is not originally a foſſil, bu a vegetable Salt; and thence to be found in ani mal Subjects †.

22. That a full Enquiry into practicable Me thods of procuring Nitre directly from vegetabl and animal Subjects, may be attended with ſuc ceſs **.

23. That ſerviceable Pot-Aſh may be mad in any Place that abounds with vegetable Sub jects ††.

24. That the Art of making Pot-Aſh is im proveable by chemical Knowledge, to the ad vantage of the ſeveral Arts thereon depend ing *.

25. Tha

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* Exp. IV. † ib. ‡ ib. ** Exp. V. †† ib. * Exp. V
† Exp. VI. and VII. ** ib. †† Exp. VII. * ib.

25. That in particular, the Art of Soap-making in *England* may be brought to much greater Perfection, by means of a mixt chemical and mechanical Enquiry *.

* Exp. VII.

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# LECTURE XIV.

## CONTAINING

## *Attempts to illustrate and improve the Business of* Colours, Dyes, *and* Stains.

1. OUR present Business is to discover the Means of producing, varying, changing, and destroying the Colours of Bodies; with a view to improve those several Arts that depend upon the use of Colours, Dyes, and Stains †. *The Subject.*

2. This we shall endeavour by Means of Experiments, performed first upon Light, and then upon selected Subjects of the vegetable, animal, and mineral Kingdoms; so as to search into the physical Causes of the Effects produced. *The Means.*

3. The *first* Experiment therefore will shew, that common Light is separable into several Colours; the *second* will be collective, or afford a variety of Instances to prove that the Colours of Bodies depend upon a certain Disposition of Parts, disposing them to reflect the differently coloured *The Heads of the Experiments.*

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† The present *Lecture* was not publickly read, as the rest were; a clear sun-shiny Day, which the Experiments require, not happening at the time.

coloured Rays of Light: The *third* princip Experiment will exhibit the Method of obtain ing thoſe *vegetable Colours* commonly called *La ques*; the *fourth* will teach the Way of preparin a certain animal Colour called *Pruſſian Blue* and the *fifth* and laſt Experiment will ſhew th Way of preparing a metalline Colour, for tin ging Glaſs red, *&c.*

## EXPERIMENT I.

*That the Rays of Light are compounded, and ſepa rable into ſeven diſtinct Kinds or Orders of Light whereon all Colours depend.*

*A leading Experiment; with the Priſm.*

4. (1) Having darkened a Room, by ſhuttin up all the Windows; and bored a ſmall Hole i a Shutter oppoſite to the Sun; if a Glaſs Priſi be properly placed againſt this Hole, we fin that an oblong and variouſly coloured Image c Light will be thrown upon the Cieling, or far ther Wall of the Room. (2) If this Image c Light be carefully examined, it will appear t conſiſt of ſeven diſtinct Colours, or differen vivid Lights, which are conſtantly found in th ſame Order; *viz.* Red in the firſt place, Orang in the ſecond, Yellow in the third, Green i the fourth, Blue in the fifth, Violet in th ſixth, and Indigo in the ſeventh or laſt: But ſlight view diſtinguiſhes only five principal Co lours; *viz.* Red, Yellow, Green, Blue, an Violet. (3) If theſe ſeveral coloured Lights b ſeparately received upon another Priſm, in th ſame manner as the Sun's Rays are by the firſt they ſuffer no farther Diviſion, or Reſolution but remain invariably the ſame: And this the do whatever figured Glaſs, Cryſtal, or Diamond be made uſe of. (4) But if the whole numbe

*The Priſmatic Colours.*

*Not farther reſolvable.*

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of theſe differently coloured Rays be received from the firſt Priſm, upon a *Lens*, or double Convex Glaſs, in the Room; they are thus blended together again, and may be thrown upon Paper, or other Body, placed at a due diſtance, ſo as to form a Spot of white and bright Light, in the Focus of the Glaſs Convex. (5) If the red Rays be ſeparately received by an opake white Body, that Body appears to be red; if the yellow Rays be ſeparately received in the ſame manner, by an opake white Body, the Body appears to be yellow; and ſo of the other Colours reſpectively: A red Body appears more vivid, or intenſely red, in the red Light; a blue Body more vivid, or intenſely blue, in the blue Light, *&c.* But all coloured Bodies appear more dead or languid in Lights of different Colours from their own; as a red Body in a blue Light, *&c.*

*Compound white Light.*

*Objects aſſume the Colour of the Light.*

5. This general Experiment is the Foundation of Sir *Iſaac Newton*'s Doctrine of Light and Colours*; and may ſhew, (1) that the Sun's Light is not a ſimple thing, but compounded of ſeven different Orders of coloured Rays; all which being exquiſitely blended together, conſtitute a perfectly white Light: (2) That theſe ſeven Orders of Rays are differently refrangible; that is, differently diſpoſed to be turned out of their way, in paſſing from one tranſparent Body into another; the red Rays leaſt, the Violet moſt, and the reſt in the Order they ſtand mentioned above: Which is the phyſical Reaſon of the Diviſion of Light into theſe ſeven Orders of Rays; and that there are therefore no more than ſeven original Colours of Light: (3) That Bodies appear of the ſame Colour with

*Light a Compound.*

*Of ſeven Colours.*

* See his *Optics*, *paſſim*.

*The Colours of Bodies from Light.* with the Order of Rays they reflect; or turn back into the same Medium from whence they were received: (4) That White and Black are no true Colours; but White an equal Reflexion of all the original Colours, and Black the Absorption of them all; for if they were returned, either mixed or unmixed, Whiteness, or some of the seven original Colours of Light, and not Blackness, would appear: (5) That the variety of Colours in natural Bodies proceeds from their differently reflecting or refracting the Rays of one, two, or several Orders, more than the rest. Thus the denominated red Bodies chiefly reflect the red Order of Rays; those denominated blue Bodies chiefly reflect the blue Rays of Light; and are thence said to be red, blue, *&c.* And all the mixed Colours of natural Bodies arise from their reflecting two or more Orders of Rays together, and absorbing or stifling the rest.

*White and Black no Colours.*

*Colours of Bodies, whence.*

## EXPERIMENT II.

*Or, Collective Instances to shew that Transparency, Whiteness, Blackness, and Colours, as considered in Bodies, depend upon certain particular Structures, Textures, or Arrangements of the Parts of Bodies; differently disposing them to transmit, reflect, refract, or absorb the Rays of Light.*

*The Texture of Bodies changed by Trisure.* 6. (1) Glass, Crystal, Diamond, Nitre, Borax, and other transparent solid Bodies, lose their Transparency, and appear white, upon their being reduced to Powder; that is, by a bare alteration of their gross Texture, or a simple reduction to smaller Parts; so as to reflect many of the Rays of Light, which they before transmitted. And the same holds of the White of Eggs whisked up to a Froth, frothy Water, *&c.*

7. Black

7. Black Talc, by being made red hot in the Fire, is turned of a Gold Colour; Syrup of Violets, by boiling Heat, loſes its beautiful Violet-Colour, ſo as at length to become pale, or colourleſs; White Loaf-Sugar, being barely melted over the Fire, without Water, immediately changes its Whiteneſs, and becomes brown; or, by a longer continuance, black; ſo that a ſingle Grain of this black Subſtance will tinge a Pint or a Quart of fair Water, or colourleſs Brandy, of a beautiful yellow, brown, or ſtraw Colour; for which purpoſe it is uſed by Diſtillers, and others *. *By Fire.*

8. All the finer coloured Flowers, as Violets, Carnations, Roſes, *&c.* loſe of their Colour, barely by being expoſed to the open Air for any long time; ſo as at laſt to appear perfectly diſcharged, or white; as if they had been expoſed to that particular Diſcharger of Colours in Silks, *&c.* the Fume of burning Brimſtone. And the ſame is remarkable of the finer or lighter kinds of Colours in Silks, or the light Blues, Yellows, and Reds, particularly the light grain-coloured Silks; all which Colours are gradually changed, diſcharged, or aboliſhed, in wearing, or by the Silks being long expoſed to the Action of the Air †. But the Scarlet Colour is more fixed and durable. And, in general, the deeper any Colours are, the more fixed and durable they prove; as being thus not Shades, as the Pinks, light Blues, *&c.* are, but true Colours, correſponding to the original Colours of Light. Add to this, that Dyers conſtantly find their Colours prove brighteſt, or ſtruck to the beſt advantage, when the Air is clear ‡. Laſtly, the blue eſſen- *By the Air.*

tial

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* See Lect. II. and XII. † See Lect. III. *paſſim.* ‡ See Lect. III. *paſſim.*

tial Oil of Camomile-Flowers loſes its Colour, and changes to a dirty Green, by being expoſed to the Air.

*By Water.* 9. Different Waters ſtrike different Colours with the ſame tinging Ingredients. Thus irony Waters turn black, or inky, with Galls, Green Tea, *&c.* And Dyers find ſome certain Waters more proper for their purpoſes than others. And, in general, the pureſt and lighteſt Waters ſtrike the beſt Colours with Dying-Stuffs. And hence it is that ſuch Waters as have, by long ſtanding, putrified, or fermented, and purged themſelves, being not filtred thro' the common Filtring-Stone, or Sand, are found to extract and communicate Colours to the greateſt advantage *.

*By Salts.* 10. Salts having a Power to alter the Textures of Vegetables; conſequently produce Changes of Colours therein. Thus moſt Flowers, whether blue or red, as Violets, Roſes, *&c.* turn green with *Alkalies:* But Violets turn red; and Roſes have their native Redneſs greatly heightened by *Acids.* So again, the yellow Roots of Rhubarb, Turmeric, *&c.* are heightened, or made redder, by *alkaline Salts.*

*The Texture of Metals leſs alterable.* 11. As Metals have a ſtrong Texture in their metalline Form; ſo they preſerve their natural Colours durably, unleſs corroded or diſſolved by their particular Menſtruums: After which, their Solutions ſtrike particular durable Colours, or afford the ſtrongeſt *Stains.*

*Iron.* 12. Iron diſſolved in ſtale Small-Beer gives the beautiful Yellow uſed in Callico-Printing; when ſublimed with Sal Armoniac, it alſo affords a Yellow. And the common Iron-Moulds made by Ink, are owing to the Iron diſſolved in the Copperas,

* See Lect. V. *paſſim.*

Copperas, whereof the common Black Writing-ink is made.

13. Copper melted with Zink, appears of a Gold Colour; dissolved in *Aqua Fortis*, it affords a beautiful Green; and in any urinous Spirit, a beautiful Blue; and the Solutions may be reduced to dry Colours, by Crystallization, or Evaporation. The same Metal precipitated with common Salt, out of *Aqua Fortis*, gives the Turquoise Colour to White Glass, when melted therewith. *Copper.*

14. Tin, a white, or colourless Metal, affords a light blue Colour, by being fluxed with Antimony and Nitre. The same Metal is necessary in striking the Scarlet-Dye, with *Aqua Fortis*, and Cochineal: Its Calx, by strong Fusion, turns to a Glass of the opal Colour. *Tin.*

15. Lead, being corroded by the Fumes of Vinegar, makes the fine White called *Ceruse*, and the white Fucus called *Magistery of Lead*; by being coloured in a strong naked Fire, it becomes Minium, or Red Lead; and this melted into Glass with Sand, is the Foundation of the Art of imitating all the coloured Gems: For this Glass it self will resemble the Hyacinth; and by the addition of prepared Gold and Tin, the Ruby *; the Sapphire with Cobalt, the Emerald with Iron and Copper, the Amethyst with Gold, and the Granat with Iron, *&c.*† *Lead.*

16. Silver, another white, or colourless Metal, being dissolved in *Aqua Fortis*, if Chalk is put to the Solution, turns of a beautiful Purple, or Amethyst Colour: And its own Solution, tho' pale as Water, durably stains the Nails, the Skin, the Hair, and other animal Substances, brown or black. *Silver.*

17. Quick-

* See below Exp. V. † See *Neri's Art of Glass*; and Mr. *Boyle's Philosophical Works*, *passim*.

*Quick-silver.* 17. Quickſilver mixed with Brimſtone, make a black Maſs; and this, by Sublimation, afford the beautiful red Pigment called *Cinnabar*, o Vermillion: And the Solution of Quickſilver being precipitated with common Salt, yields ſnow-white Powder; which alſo turns black, b being mixed with Sulphur.

*Gold.* 18. *Gold*, diſſolved in *Aqua Regia*, affords fine yellow Liquor; which ſtains animal Sub ſtances beautifully purple: And if the Solutio be ſufficiently weakened with Water, and mixe with a Solution of Tin, a fine red or purpl Powder may be thus obtained for ſtaining Glaſ moſt beautifully red *.

*Minerals.* 19. Many mineral Subjects are natural Pig ments; as native Cinnabar, Ochre, Black Lead *&c.* but particularly the yellow Earth calle *Light Ochre*, found in *Shottover* Hills, which i uſed native as a light Yellow, and by Calcina tion makes a light Red. This Colour *Englan* ſupplies *Italy* with; and *Le Gar* would frequentl ſay he had been no Painter without it †.

*Experimental Inſtances of Colours produced, deſtroye and regenerated upon ſimple Mixture.*

*A colourleſs Liquor affording Colours by Mixture.* 20. (1) Put dry Red Roſe-Leaves into Spiri of Wine; and, by ſtanding a little therein, th Roſe-Leaves will loſe their red Colour, withou manifeſtly tinging or altering the Liquor; the add a little Oil, or Spirit, of Vitriol thereto and the Liquor will appear of a Red Colou But if a little alkaline or urinous Spirit be poure to the Mixture, the Red Colour preſently chan ges to a Green; which, by the addition of littl

* See hereafter Exp. V.
† See below Exp. V. § 67.

ttle more Spirit of Vitriol, turns to a red Co-
our again.

*Colourless Liquors producing Blackness.*

21. (2) Make a slight Infusion of bruised Galls in Water, so as not to discolour the Wa-er; filtre the Infusion; make also a weak So-ution of Green Vitriol in Water, and filtre the iquor, so that they may both appear pellucid: hese Liquors being now mixed together, an ky Blackness will immediately arise; but if a ttle Oil of Vitriol be added to the Mixture, e Blackness will, by degrees, totally vanish, nd the Liquor appear pellucid again; tho' the lackness may be recalled by the addition of a ttle Salt of Tartar.

*A white, solid, and pellucid Fluid turned into Blackness.*

22. (3) If a little bruised Camphire, which a very white Substance, be put into pellucid il of Vitriol, and the Containing Glass be ook for some time, the Camphire will dissolve, nd gradually change the Mixture to a Brown, nd at length to a full Black. But upon the ldition of fair Water, the Blackness entirely nishes, and the Camphire rises to the top in s pristine Form, and native Whiteness *.

*A Liquor differently coloured as differently viewed.*

23. (4) If the Shavings of *Lignum Nephriti-m* be infused for some time in cold Water, and e clear Liquor be decanted into a clean Glass, nd viewed from the Light, the Liquor will ap-ar of a beautiful Blue; but if viewed towards e Light, of a Yellow. If a little Spirit of itre be put to this Liquor, it loses its Power reflecting the blue Rays; but the addition of little Oil of Tartar, *per deliquium*, recovers at Power again.

*Its Colour destroyed and recovered by Mixture.*

*Red changed into Purple by Mixture.*

24. (5) If Logwood be infused in Water, it ves a red Colour; which, upon the addition of



* 'Tis also remarkable, in this Experiment, that the strong ent of the Camphire is absolutely wanting in the black Solu-n; but recovered upon the addition of the Water.

of a little Spirit of Urine, turns to a fine Purple But this may be changed to a dilute Red, by dropping in a little Spirit of common Salt.

*Red Colours heightened and lowered by Mixture.*

25. (6) An Infusion of *Brazil* Wood, o Cochineal, in Water, is much heightened, i its red Colour, by the addition of Spirit o Urine; and lowered or turned paler by the Spi rit of Salt.

*A pellucid Liquor made blue by a white Body.*

26. (7) If Spirit of Wine be digested upo recent Camomile-Flowers, and distilled ove from them in a Glass Retort, the Spirit wi thus acquire a beautiful blue Colour; whic may be made deeper by being drawn over agai from fresh Flowers.

*A blue Colour destroyed by Mixture.*

27. (8) A beautiful blue Tincture being mad by digesting Spirit of Urine upon Filings of Cop per, the addition of a little Oil of Vitriol en tirely destroys the blue Colour; as a little Spir of Salt turns it to a Green.

*Pellucid Liquors made red by Mixture.*

28. (9) Pellucid Oil of Vitriol being mixe with pellucid Oil of Turpentine, or the essenti Oil of Aniseeds, or more particularly with O of Cloves; they thus turn into a thick, re Balsam. And so again, if a pellucid commo Oil be, by means of a little Wax, and continue Triture, gradually mixed with fair Water they thus unite into a very thick, white Sub stance, Balsam, or cold Cream.

*A white Powder made yellow by Water.*

29. (10) Oil of Vitriol being distilled ov from Quicksilver, leaves a white Powder b hind; to which if Water be poured, the Powd presently becomes of a beautiful Yellow.

*The same Solution affording differently coloured Precipitates.*

30. (11) To a Solution of Quicksilver, Spirit of Nitre, add Spirit of Urine; and a whi Powder will be precipitated: To another parc of the same Solution add Oil of Tartar, *per de quium*, and a yellow Powder will fall to the bo tom: To a third parcel of the same Soluti

ac

add Spirit of Urine, and the Precipitate obtained will be of a Fleſh-Colour.

31. (12) If a clean new Pen be dipped in Spirit of Vitriol, and the common deep Blue Paper be wrote upon therewith, the Letters appear of a very bright and beautiful Red: And, in the ſame manner, pellucid Spirit of Salt ſtains a black Hat red. *Limpid Ink appearing red.*

32. (13) A pellucid Solution of *Saccharum Saturni* in Water, being wrote with, becomes inviſible upon the Paper, when dried: But the bare Fumes of another tranſparent Liquor, *viz.* an Infuſion of Quicklime and Orpiment in Water, will ſoon render the inviſible Writing black and legible. And thus thoſe commonly called Inviſible or Sympathetic Inks are made. *Inviſible Ink.*

33. (14) The volatile Salt of Sal Armoniac, a white Body, and the Cryſtals of Copper, a green one, will, by mixture, become Purple. *A white and green Body makes Purple.*

34. (15) Salt of Steel, a green Body, and Sugar of Lead, a white one, being mixed together, the ſurface of the mixt Powder will appear red; whilſt the internal parts are of a dirty white. *A Green and White, red on the Surface.*

35. (16) That original, and ſimple, as well as compound, Colours, are producible by Mixture, appears from many Experiments.

36. (17) If the Sun's Rays paſs thro' two pieces of differently coloured Glaſs, for Inſtance, a blue and a yellow piece, laid upon each other, and theſe Rays be received from the Glaſſes upon white Paper, they then appear of a beautiful Green. *A Green from Light paſſing thro' blue and yellow Glaſs.*

37. (18) It is common with the Dyers, to dye the Cloth firſt Blue with Woad, and turn that Blue into a Green by the Yellow called *Dyers Weed*, or *Luteola*. *Greens dyed from blue and yellow.*

*Green from a blue and yellow Liquor.*

38. (19) To a fine yellow Solution of pure Gold, in *Aqua Regia*, add a deep blue Solution of Copper in Spirit of Urine; and the Mixture will appear green.

*From blue and yellow Ammel.*

39. (20) Blue and yellow Ammel, being melted together, conſtitute a green one.

*Many Painters Colours by Mixture.*

40. (21) The Painters make a great variety of compound Colours, by mixing two, three, or more different Colours together, either on their *Pallat*, or the Canvas.

*Mixed Colours may make White.*

41. (22) A mixture of the ſeven, or even five, original Colours, will make a White; and the more perfectly, the finer and more perfect the coloured Bodies are. Thus, if a large Top be painted on its upper Surface, one part Red, another Yellow, another Green, another Blue, and another Violet; this Surface, whilſt the Top is ſpinning briskly (ſo that the motion ſhall confound the ſeveral Colours, or make them appear mixed to the eye) will exhibit a dirty kind of Whiteneſs. And in like manner, by mixing together Powders of different Colours, as Vermillion, Orpiment, Indigo, Verdigreaſe, *&c.* in proper proportions, the compound Powder will, in a ſtrong Light, appear to be white. And if differently coloured Flames could be brought to mix, this Experiment might be made in greater perfection.

*Flames of different Colours.*

42. (23) Flames are of different Colours according to the Bodies that produce them. Thus the Flame of burning Camphire is white like the Focus of a Burning-Glaſs; the Flames of Spirit of Wine, and Sulphur, are blue; the Flame of White Wax is white, inclining to blue; that of Tallow, white, but rather inclining to yellow, *&c.* Whence proceeds the difference of the Colours of Bodies, as viewed by Day-light, Candle-light, Fire-light, ſulphurous Light

*&c*

*&c.* And, for making Experiments to this purpoſe, Oil might be impregnated with certain Metals, as particularly Copper and Iron, by Triture, and Digeſtion, ſo as to exhibit their particular Flames.

43. (24) The Priſmatic, or original Colours may be imitated to conſiderable perfection in Liquors, where the Parts of the tinging Subſtances are rendered extremely minute or fine. Thus a Solution of Cochineal in Spirit of Urine, viewed in a ſtrong Light, affords a moſt vivid and beautiful Red; a Solution of Copper in Spirit of Urine, yields a glorious Blue; a Solution of Verdigreaſe in diſtilled Vinegar, is an excellent Green; a Solution of Gold in *Aqua Regia*, makes a fine Yellow; an Infuſion of Violets in hot Water, affords an excellent Violet Colour, *&c.* And from a thorough Acquaintance with theſe Liquors, and the Methods of varying, mixing, and heightening their Colours, many Improvements in the Arts depending upon Colours, Dyes, and Stains, might be rationally expected. *The Priſmatic Colours imitated.*

44. (25) The foregoing Set of Experiments not only confirms the former leading Experiment made with the Priſm, but alſo Sir *Iſaac Newton*'s general *Doctrine of Colours:* For it is hence manifeſt, that ſlight mechanical alterations in Bodies, produce, alter, or aboliſh all kinds of Colours therein; or that all the Colours of Bodies are only original Colours of Light, differently reflected, either in a ſimple or variouſly compounded State, according to the particular Diſpoſition, Texture, Mixture, or Arrangement of the ſmall Parts of the reflecting Body, ſo as to afford that infinite variety of Colours we meet with in natural and artificial things. *Reſult of the Experiments.*

## EXPERIMENT III.

### *The Method of preparing the vegetable Colours called* Laques.

*The Laque of Turmeric.*

45. Take a Pound of Turmeric-Root, reduced to fine Powder, three Pints of fair Water and an Ounce of Salt of Tartar; put them into a glazed earthen Veſſel, and let them boil together, gently, over a clear Fire, till the Water appears richly impregnated with the Turmeric, or will ſtain a piece of white Paper beautifully yellow; then filtre the Liquor, and gradually add to it a ſtrong aqueous Solution, of Roch-Allum, till the yellow Matter is all curdled together, or precipitated: After this, pour the whole into a Filtre of Paper; where the aqueous part will run off, and leave a yellow Matter behind; which being edulcerated, or waſhed in the Filtre, by the repeated affuſion of freſh Water, till the Water comes away inſipid, and afterwards dried, it becomes the *Laque of Turmeric*, or a beautiful yellow Colour for Painting.

*The general Way of obtaining Laques.*

46. This Experiment ſhews a general Method of obtaining a Laque from all the vegetable Subjects fitted to afford it: For in the ſame manner may a red Laque be made from Madder, Brazil, and many other dying Woods or tinging Vegetables. But where the Colour of the Subject depends upon a very ſubtil Texture, Mixture, or Arrangement of the Parts, this Method deſtroys, or at leaſt impairs, the Colour; as particularly in Violets, Red Roſes, Carnations, *&c.* So that it ſeems applicable only to the tinging Vegetables of a ſomewhat ſtrong and firm Texture.

47.

47. In some cases also a simpler Process is sufficient to obtain rich *Laques*; particularly that beautiful red one emphatically called *Laque*; and from which the Name seems to be derived to the rest. This red *Laque* is obtained barely by boiling *Stick-Lac* in Water; then filtring the Decoction, and evaporating the superfluous Humidity: For the beautiful red Colour adheres to the outsides of the Sticks broke off the Trees, along with the *Gum-Lac*; and readily communicates itself to boiling Water*. Some of this tinging Matter likewise sticking to the Gum itself, it is proper to boil them both together: For the Gum does not prejudice the Colour, nor dissolve in boiling Water: So that after the Operation the Gum is as fit for the making of Sealing-Wax, or other Uses that do not require the Colour, as it was before. *The particular Laque of Stick-Lac.*

48. And much after the same manner is that extremely rich and beautiful red Colour called *Carmine* prepared from Cochineal and a Solution of Tin; for Carmine may be conceived as no more than the Scarlet, or Bow-Dye Liquor, concentrated, or reduced to what the Painters call a *Body*. *Carmine.*

49. How far our present Experiment may be applicable to other parts of the *Materia tinctoria*, seems not hitherto well considered. Doubtless it might afford a great variety of *new Colours*, by a proper Extension and Diversification in the *Menstruum* and *Method*. For Example: If *Red Saunders* be digested warm in Spirit of Wine, *Extension of the Experiment.*



* The tinging Matter adhering to the Sticks and Gum, is perhaps not a vegetable, but animal Substance; somewhat of the nature of Cochineal, and deposited in form of an Excrement, by a certain kind of Bees, in the *Indies*. See a Paper upon this Subject in the *French* Memoirs; see also Mr. *Boyle* upon human Blood. Abridgm. Vol. II. p. 481.

*A red Rosin from red Saunders.*

the Menstruum acquires a deep red Colou and if drawn off by Distillation, leaves behir it a red, tasteless, and inodorous *Rosin*, th affords no Smell even upon burning, nor dissolv in any expressed or essential Oil; yet, even a small proportion, tinges Spirit of Wine of full red Colour, so as to render it useful f anatomical Injections, *&c.*

*Another from Red Wine Lees.*

50. In like manner may a particular gumm red Substance, or Pigment, be obtained, by Sp rit of Wine, from dried Red Wine Lees; ar whether the tinging parts of the more cumbe some dying Woods and Stuffs could not be a vantageously extracted, at the Places of the Growth, so as to leave their ponderous Bu behind, and bring away only their concentra ted, essential Colours, might deserve the cons deration of the Merchant, the Dry-Salter, th Dyer, the Callico-Printer, *&c.* It might b tried in Log-Wood, Campeche, or Brazil; Madder, Safflore, and many other dying Woo and Stuffs, whose Names we seldom meet wit but in the *Bills of Entry*.

## EXPERIMENT IV.

### *The Way of preparing an animal Colour called* Prussian Blue.

*The Process for making Prussian Blue.*

51. Take of crude Tartar and Nitre, eac four Ounces; pulverize, and mix them toge ther; and, by Decrepitation, bring them to fixed Salt; which being powdered hot, add t it four Ounces of thoroughly dried Ox-Bloo reduced to fine Powder: Calcine the Mixtu in a close Crucible; whereof it may fill tw thirds: Then lightly grind the Matter in Mortar, and throw it hot into two Quarts boilin

boiling Water; boil them together for half an Hour; afterwards ſtrain off the Liquor, waſh the black remaining Subſtance with freſh Water, and ſtrain as before; continuing to do thus till the Water poured off becomes inſipid. Put the ſeveral Liquors together, and evaporate them to two Quarts. Now diſſolve an Ounce of green Vitriol, firſt calcined to Whiteneſs, in ſix Ounces of Rain-Water, and filtre the Solution. Diſſolve alſo half a Pound of crude Allum in two Quarts of boiling Water; and add this to the Solution of Vitriol, taken hot from the Fire; pouring to them likewiſe the firſt Lixivium, whilſt thoroughly hot, in a large Veſſel: A great Ebullition and a green Colour will immediately enſue. Whilſt this Ebullition continues, pour the Mixture out of one Veſſel into another, and afterwards let it reſt; then ſtrain the Liquor thro' a Linen Cloth, and let the Matter, or Pigment, remain in the Strainer; from whence put it, with a wooden Spatula, into a ſmall new Pot; pour upon it two or three Ounces of Spirit of Salt; and a beautiful blue Colour will immediately appear. Let the Matter be now well ſtirred; then ſuffered to reſt for a Night; afterwards thoroughly edulcerate it by repeated Affuſions of Rain-Water; allowing a proper time for the Precipitate to ſubſide: And thus, at length, it will become exquiſitely blue. Laſtly, let it drain upon a Linen Strainer, and dry it gently: By all which means it becomes the Pigment that goes by the Name of the *Pruſſian Blue*.

52. The ſucceſs of the Experiment has a great dependence upon the Calcination. The Crucible is firſt to be ſurrounded with Coals, at ſome diſtance; that it may grow gradually hot, and the Matter leiſurely flame and glow. Let this degree

*The Cautions required in it.*

degree of Heat be continued till the Flame and Glowing decreaſe; then raiſe the Fire again that the Matter may glow with an exceeding white Heat, and but little Flame appear above the Crucible. The Lixiviums ſhould be very hot, and mixed together with the utmoſt expedition *.

*Its Nature.* 53. The Method of making this *Pruſſian Blue* in perfection, has been held and purchaſed as a very valuable Secret, both in *England*, *Germany*, and elſewhere; but it is now got into ſeveral hands. Its Proceſs is very extraordinary, and could ſcarce be derived *a priori*, from any reaſoning about the nature of Colours. 'Tis allowed an excellent blue Pigment, and by ſome preferred to *Ultramarine*; tho' its durability might have been ſuſpected, from the vegetable and animal Matters uſed in its Preparation, if the Colour did not ſeem wonderfully fixed by the Operation.

*Many animal Matters uſed in Colours.* 54. A great variety of Colours are prepared by the means of animal Matters; and more particularly by the means of Urine; which when it has ſtood to ferment, or putrify, ſerves to extract, change, or fix the natural Colours of ſome Bodies; and to heighten the Colours of others. Thus it is uſed in the preparation of the ordinary Blue called *Archol*; which chiefly comes to us from *Holland*: It is alſo uſed in the changing or fixing of *Turnſol*; ſo as to make a moſt elegant Red from the Sun-Flower: It is alſo a principal Ingredient, along with *Indigo*, in making that noble, fixed, and durable Blue, very lately diſcovered in *England*, for the ſtaining of Callico; a Colour that firſt appears Green, but

*Particularly Urine.*

* See *Philoſophical Tranſactions*, No. 381.

ut by washing with Soap, changes, and fixes
nto a lovely Blue.

55. Certain chemical Preparations from ani- *The Spirit of Urine, &c.*
al Subjects are likewise employed for extract-
g, changing, or heightening the Colours of va-
ous Bodies. Thus the alkaline, or volatile,
pirit of Urine, Blood, Bones, *&c.* extracts a
ne Blue from Copper, changes a green Solution
Copper to a Purple, and heightens the Red
Cochineal. And doubtless the present stock
Colours might be considerably enlarged, or
nproved, by a prudent Choice of *animal Men-*
*uums.*

56. By animal Menstruums we mean both *Animal Menstruums, natural.*
e natural and artificial kind: The natural are
ch as Blood, Serum, Gall, Urine, *Saliva*,
ennet, Whey, Butter-milk, *&c.* most of which
ing properly employed, will either discharge
produce Colours. Thus recent Urine dis-
arges the common Ink out of Linen; the *Sa-*
*va* discharges Red Ink; Butter-milk takes
ains and Mildews out of Linen, *&c.* Blood,
e see by our present Experiment, affords a
h and beautiful Blue; and Gall is a natural
llow; which may deserve to be treated as
ood, in making the *Prussian Blue.*

57. These natural animal Menstruums, or *And artificial.*
her animal Substances, being chemically treat-
, may afford a great variety both of simple
d compound Liquors, or new artificial Men-
uums, for farther improving the Business of
lours, Dyes, and Stains. Thus, as putrified
rine affords an alkaline Spirit, by Distillation,
at serves to produce, alter, or destroy a great
mber of Colours; so likewise might the Li-
uors obtained, by Distillation, from recent, or
rmented Whey, Butter-milk, *&c.* And by
riously compounding these several Substances,
or

or Liquors, even by random Trials, or chan Experiments, ſome new Diſcoveries in Colou might be made; as in the preſent Experime of the *Pruſſian Blue:* Tho' we have a muc greater dependence upon conducting ſuch Exp riments in a rational manner; or in the way an Art, formed upon a competent knowledge chemical Operations, with their Productions ar Effects; which will enable the Enquirer to rea ſon, by Analogy, from one Experiment to ar other; and thus lead, in a ſure and guarde manner, to new Inventions and Diſcoveries.

*The Experiment extended.*

58. Thus, for Inſtance, the chemical Opera tor having found that common Bones, burnt on to Blackneſs, afford the Bone-black; it is eaſ to transfer the Experiment to Ivory, whereby better Black is produced. And thus, upon find ing that dried Ox-Blood has ſo great an effe in making the *Pruſſian Blue*, we are naturall led to try the ſame Experiment with the Bloo of different animals; or other concreted anima Juices, as Gall, Feathers, Fleſh, Leather, & or the entire Bodies of certain Inſects, Fiſh Birds, *&c.* And this ſhould be done with pro per Diverſifications of the Ingredients, and thei Proportions; all along carefully noting the feve ral Phænomena and Events; which will conſtant ly afford Light and Inſtruction to the Mind, fo the better regulating and conducting of th Enquiry, till it ends in a full Diſcovery.

## EXPERIMENT V.

### *The Way of preparing a metalline Colour, from Gold and Tin, for tinging Glaſs of a beautiful Red.*

59. Diſſolve Gold in *Aqua Regia*, and dilut the fine yellow Solution with a large proportion of

f fair Water; to the mixture add a ſufficient uantity of a ſaturated Solution of Tin, made ſo in *Aqua Regia*, at ſeveral times; and a moſt eautiful red, or purple-coloured Powder will on fall to the bottom of the Containing-Glaſs. ecant the Liquor, and dry the Powder; a w Grains whereof being melted along white yſtalline Glaſs, will tinge the Glaſs through-ut of an extremely fine purple or ruby Co-ur *. *The Ruby of Gold.*

60. By means of this Experiment the ancient rt of Staining Glaſs red, long ſuppoſed to be ſt, ſeems at preſent reſtored. All the Colours e eaſily given to Glaſs; as we mentioned ove †: But this ſeems to have been kept as a cret in very few hands, till lately; and may conſiderably diverſified, ſo as to introduce a ateful variety of beautiful red and purple olours in Glaſs ‡. *Its Uſes, in the Art of Glaſs.*

61. It ſhould alſo ſeem that the Art of Cal-o-Printing, which now wants a Red, equally rfect with the Blue it has lately obtained, ght hence be furniſhed with ſuch a Red; tho' ere is reaſon to ſuſpect it might come out too ar for ordinary uſe. But as the Perfection this Art conſiſts in diſcovering fixed, bright, d permanent Colours, not ſubject to change the worſe in the open Air; ſuch Colours uld rather be expected from mineral or me-lic Matters, than from thoſe of the ve-table and animal Kingdoms; which uſually ord Subjects of too lax and alterable a Tex-e for permanent Colours, unleſs they could ſome way ſubſtantially fixed. *In Callico-Printing.*

62. It

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* See *Caſſius de Auro*, p. 105. † See Exp. II.
‡ See Mr. *Boyle's* Philoſophical Works. Abridgm. Vol. I. 457—459.

*The* Indian *Colours how made.*

62. It appears highly probable that the *dians*, for making the fine, bright, and durab Colours wherewith their Callicoes and Chinch are ſtained, uſe metalline Solutions; for ſo ſtained Callicoes having been kept for forty fifty years, the bright Colours have been o ſerved to eat out the Cloth, exactly in the ſa manner as the corroſive, acid Spirits, whi diſſolve Metals, are found to do: Whence, imitate their richeſt and nobleſt Colours, we a directed to uſe proper metalline Solutions, ma after the manner of our preſent Experiment.

*The higheſt Improvement of Colours.*

63. But it would be a farther ſtep towar Perfection, not only in this Art, but alſo in t Art of Painting, to prepare the fineſt Colou without employing either acid or alkaline Salt which uſually ſubject Colours to change, or el are apt to prey upon the Cloth, or Canvas, we ſee in Verdigreaſe, the blue and green Cry ſtals of Copper, *&c.* Whence we are directe (1) to ſearch for Menſtruums that are neith acid, alkaline, or ſaline; (2) for ſuch metallin *Calxes*, Precipitates, or Powders, as will n loſe their Colours by being well waſhed, to g out their Salts; (3) to prepare certain metallin Matters by Calcination, or the bare aſſiſtan of the Fire; and (4) to look out for *native C lours*, wherein no ſaline Matter abounds.

*Variation and Extenſion of the Experiment, by Triture.*

64. (1) It may be worth the trying, whethe certain Metals are not ſoluble by Triture, wit the pureſt Oils employed in Painting, and ſuc as contain neither acid nor alkaline Salts; o whether mere Water, the White of Eggs, Sali va, Gum-Water, *&c.* may not, by the ſam means, be made to diſſolve them; ſo as that th metalline Particles may be left behind upon Cal licoes, Cloths, *&c.* when the aqueous or mucila ginous Matter is dried, or waſhed away fron them

nem. But no great effect can be rationally ex-ected in such attempts, unless the Triture be ng continued, and Mills, or other well adapt-d Engines, be used for the purpose: For we nd, in all Instances, that Metals must be redu-ed to very fine Particles before they will tinge r colour.

65. (2) The Pigments or Colours obtained y Crystallization, such as the blue and green itriols, or Crystals of Copper, *&c.* cannot be eprived of their aqueous or saline Parts by a ry Air, or by washing, without suffering ex-eme alterations, or being left in the form of a ross, terrestrial Matter, differently coloured rom what they were at first. Thus the fine reen Crystals of Iron, by being exposed to the ir, become white; and when well washed in Vater, lose their Greenness, and turn to a ddish or yellow-coloured Ochre, or Earth: nd if deprived of their saline and aqueous rts, by a strong Distillation, they leave be-nd a brown or red *Caput mortuum*; which being ashed in Water, affords not a green, but a rown-coloured Pigment, or kind of *Spanish rown*. And as this holds proportionably of her Colours obtained by Crystallization, there e little hopes of procuring durable Pigments y that Operation, which shall be of the same olour with the Crystals themselves; tho', after ing well washed, different Colours may be us procured. *By Crystallization, Lotion, and Distillation.*

66. (3) Metalline and mineral Matters are ducible to a considerable degree of subtilty or allness of Parts, by Fire, or dry Calcination; as to leave them durably possessed of their na-ve or adventitious Colours. Thus *Lapis La-uli*, by being calcined, becomes the fine, du-ble, rich Blue, called *Ultramarine: Light Ochre*, by *Dry Calcination.*

by the ſame treatment, becomes a *light Red* or the moſt uſeful Fleſh-Colour in Painting Lead, by Calcination, becomes durably red and Iron, durably brown. But a proper Method ſeems wanting for the dry Calcination of the nobler Metals, Gold and Silver: Though for the uſes of Gilding, *&c.* theſe nobler Metals are eaſily coloured, by dipping linen Rags into their reſpective Solutions; then drying the Rags, and ſetting them on fire, ſo as that they may burn to Aſhes; whereby a dry and fine metalline Powder is readily obtained.

*New and durable mineral Pigments diſcoverable.*

67. (4) Many native mineral Pigments, or durably tinging Subſtances, are already diſcovered, that do not abound with Salts; ſuch as Ochre, both yellow and red, Cinnabar, or Vermillion, Zaffora, Manganeſe, *&c.* and doubtleſs many others might be found in Countries that are ſtored with Mines, or where a proper ſearch is made after new mineral Subſtances †.

*Ores tried by the ſtaining of Glaſs.*

68. Our preſent Experiment likewiſe affords an uſeful Method of examining Ores, or diſcovering a ſmall proportion of a metallic Subſtance in a large proportion of Earth, *&c.* for a quantity of pulverized cryſtalline Glaſs being ready at hand, it is but mixing a little of the Ore, or mineral Matter, therewith, and melting them together; whereby the Glaſs will be deeply or lightly tinged of a certain Colour, according to the nature and quantity of the Metal contained in the mineral Matter. Thus a little Silver tinges white Glaſs yellow, Copper green, *&c.* *Putty*, or a mixture of calcined Tin and Lead, turns it white, *&c.* tho' theſe Colours will ſomewhat vary, according to the mixture of the metalline Matters with others, the regulation of the Fire and

* See above Exp. II. § 20. † See ib.

and other Circumſtances: So that a Sett of particular Experiments are required, to bring this affair to greater certainty, and reduce the whole to a regular *Table*. But this Method, if ſufficiently verified, might be commodiouſly uſed, when the quantity of Ore, or mineral Matter, is ſmall, or contains but a very minute proportion of Metal; for a little metalline Matter will thus tinge a large proportion of Glaſs.

69. The Art of Enamelling in Glaſs alſo depends upon a prudent uſe of mineral Pigments; or a mixture of Miniature-Painting and Annealing: For the Method here is, to lay the Colours upon Glaſs, as the Painter does upon Canvas; and afterwards to ſoften the Glaſs, by a proper degree of Heat, in the Annealing-Furnace, under a Muffle, till the Colours ſink into the Glaſs. And in this manner alſo is Glaſs frequently coloured, on its more ſuperficial parts, without being tinged throughout; as we ſee in the coloured Glaſs of certain Church-Windows, and ancient Buildings. *The Art of Enamelling.*

## AXIOMS and CANONS.

1. The preceding Enquiry ſhews, That the *Phyſical Cauſe* of the Generation, Variation, and Deſtruction of Colours in Bodies, is the different Refrangibility and Reflexibility of the different Orders of the Rays of Light *.

2. That Colours therefore are not inherent in the Bodies ſaid to be coloured; but rather in the Rays of Light which fall upon them; and are thence reflected to the Eye, ſo as to cauſe the *Senſation of Colour* †.



* Exp. I. II. † ib.

3. That Colours, ſo far as they may be conſidered in the Bodies ſaid to be coloured, depend upon a certain mechanical Texture, or Mixture of the ſmall parts of Bodies; which Texture, or Mixture, being altered, or deſtroyed, the Colours alſo are altered, or aboliſhed*.

4. That Whiteneſs in Light is an intimate Mixture of the ſeveral Orders of Rays; and Whiteneſs in Bodies, the actual Reflexion of their Rays in their natural, mixed, or unſeparated State †.

5. That Darkneſs is the Abſence of the Rays of Light; and Blackneſs in Bodies, not a Colour, but the want of thoſe Rays being reflected from the ſurface of the Bodies ſaid to be black; or, in other words, that Blackneſs is produced by the Rays of Light being abſorbed ſtifled, or drank in, by the Bodies denominated black ‡.

6. That *Tranſparency* in Bodies is their tranſmitting the Rays of Light; and *Opacity* their not tranſmitting, but reflecting theſe Rays **.

7. That common Light is compounded of ſeven different original Orders of Rays; *viz.* Red, Orange, Yellow, Green, Blue, Indigo and Violet; and that according as Bodies reflect more or leſs of theſe Rays, ſuch Bodies appear of different ſimple or compound Colours ††.

8. That great Alterations of Colours are producible by a bare Alteration of the Arrangement, Texture, or Mixture of the ſmall Parts of Bodies; or by the Interpoſition of different Parts, upon bare Triture, and ſimple Mixture ‡‡.

9. That vegetable and animal Colours are, in general, leſs durable, or more ſubject to change than

* Exp. I. II. † ib. ‡ ib. ** ib. †† ib. ‡‡ Exp. II. III. IV. V.

than the mineral kind; on account of the looſer, or more porous Nature and Texture of the two former, and the ſtronger and cloſer of the latter *.

10. That the Arts of Enamelling, and imitating Precious Stones, in Glaſs, depend upon the Addition of metalline *Calxes* to the Glaſs of Lead, or pure cryſtalline Glaſs, in Fuſion; and that an infinite variety of the moſt durable and beautiful Colours are obtainable by this means †.

11. That many new Colours may be reaſonably expected from a proper Enquiry into, and a chemical Treatment of, various Subjects of the vegetable and animal Kingdoms ‡; and that there are four principal Ways of obtaining new, fixed, or durable mineral and metalline Colours; *viz.* (1) by diſcovering new *Menſtruums*; (2) by finding ſuch metalline Powders as will bear to be waſhed from their adhering Salts; (3) by the proper application of dry Calcination; and (4) by enquiring after native mineral Colours that are not ſaline **.

12. That a great variety of new and fixed Colours may be prepared from Metals, and their Menſtruums, or certain Mixtures of metalline and mineral Matters, for the farther Service and Improvement of the ſeveral Arts that depend upon Colours, Dyes, and Stains ††.

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* Exp. II. III. IV. V. † Exp. II. V. ‡ Exp. III. IV.
** Exp. V. †† Exp. II. III. IV. V.

# LECTURE XV.

## CONTAINING

## *Attempts to illuſtrate and improve the common Ways of preparing Remedies.*

*The Subject.*

1. THE Buſineſs we are now entering upon is Pharmacy; a Subject which has almoſt engroſſed Chemiſtry to itſelf: Whence many underſtand by Chemiſtry little more than the Preparation of Medicines. This notion is countenanced by the Books of Chemiſtry generally publiſhed; which ſeldom contain more than Directions for the making of Medicines: So likewiſe the Courſes of Chemiſtry uſually given, turn chiefly upon the Application of Chemiſtry to Pharmacy.

2. That Chemiſtry is applicable to the Illuſtration and Improvement of many other Arts we hope to have ſhewn in the preceding Lectures. But as the application of it to Pharmacy is a thing of importance to Life and Health; and as men generally think that this is the principal office and uſe of Chemiſtry; we judge it proper to beſtow two Lectures upon the Subject. In the firſt whereof we propoſe to conſider the preſent State of Pharmacy, with the means to improve it, upon the footing it now ſtands; and in the ſecond we will endeavour to ſhew how it may be reduced to a greater degree of ſimplicity; and thus be brought nearer to perfection. The one we may call the *copious*, and the other the *conciſe* method of Pharmacy.

3. W

3. We define *Pharmaceutical Chemiſtry*, the Art of directing and performing the ſeveral Proceſſes, or Ways of working; whereby natural Subſtances are reducible to artful Medicines. *Pharmaceutical Chemiſtry.*

4. And thus the whole Art conſiſts of two Parts, or a *Theory* and a *Practice*: The Theory is claimed by the Phyſician; and the Practice is turned over to the Apothecary.

5. Moſt of the natural Bodies being ſome way or other employed as Subjects of Pharmacy, the *Materia medica* is extremely large, and its Operations various. Its Materials in the earlieſt ages indeed were few; and the ways of managing them were ſimple: Subjects afterwards multiplied; Operations increaſed; and at preſent we ſeem abundantly ſtocked with both ſimple and compound Medicines. *Hiſtory of Pharmacy.*

6. But the Hiſtory of Pharmacy may deſerve to be more particularly treated; in order to ſee by what means it arrived at its preſent State, and how it may be farther advanced.

7. Diſeaſes muſt have been early, if the firſt Inhabitants of the World experienced the ſame changes of Seaſons, breathed the ſame kind of Air, and uſed a like Diet, and Regimen of Life, with ourſelves. But ſoon after a Diſeaſe afflicts, the Patient ſeeks for a Remedy: Whence we may reaſonably ſuppoſe that this was the Foundation of Pharmacy in various Parts of the World.

8. Experiments being thus multiplied, and the Event gradually introducing better Methods of preparing the Simples, Pharmacy would begin to appear in the form of an Art: Yet when *Hippocrates* came to compile a kind of Syſtem of Phyſic, from the Obſervations of Antiquity, he deſcribed but few, and thoſe were generally ſimple.

9. Succeeding Phyſicians enlarged the *Materi medica: Galen* conſiderably ſwelled the Cata logue; which received many additions from th *Arabians.*

10. And when Learning began to revive i *Europe*, the *Materia medica* was again enlarge and great changes wrought upon it by Chem ſtry: Whence Chemiſtry at length was genera ly received, and acknowledged of uſe in Pha macy.

11. Both the *Galenic* and Chemical part this Art are now extremely copious. Neceſſit gave the Occaſion; Nature ſupplied the Mate rials; and Art and Obſervation diſcovered the Preparations, Virtues, and Uſes.

12. Thus we at preſent ſeem provided of competency of ſtanding Medicines; and hav by degrees, acquired a Method of preſcribin in *extemporaneous Forms.*

13. The Art of Pharmacy may be conſidere under the management of *Phyſicians*, Apothec ries, trading Chemiſts, and Druggiſts.

14. It is the office of the Phyſician to dire the Medicines; or give the Rules of extractin compounding, and managing the Simples. the Phyſician therefore ſhould be defective this part, let the Apothecary, the trading Ch miſt, and the Druggiſt, be ever ſo juſt, or ev ſo knowing, the Art of Pharmacy muſt fall ſho of Perfection.

15. To the *Apothecary* belongs the reductio of the *Materia medica* into certain forms of M dicines, according to the direction of the Ph ſician.

16. But there are two kinds of Apothecarie vulgarly known by the names of *wholeſale* a *retail* Apothecaries. 'Tis the latter alone v are here concerned with: Theſe act by Rul

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generally follow their Standard, and compound with Art and Care; tho' they will ſometimes ſubſtitute *quid pro quo*, and now and then venture to reverſe an Order. According to their skill and care, they are more or leſs liable to be impoſed on by the Druggiſt, and the trading Chemiſt; all of them uſually ſelling what they buy. But if the Apothecary be here often deceived, how ſtands it with the Patient and Phyſician? or what is the ſtate of Pharmacy?

17. The retail Apothecaries, however, deal more in *Subſtitution* than in *Sophiſtication.* The prudent Phyſician therefore preſcribes what is uſually kept, and proper to keep, in the Shops, or what is otherwiſe eaſily obtainable. If there are other abuſes committed in this part of Pharmacy, they may perhaps be chiefly attributed to ſome want of skill or conduct in the Phyſician.

18. The deſign of the trading Chemiſts and Druggiſts is to furniſh medicinal Matters to the Apothecary, who cannot always detect an artificial Counterfeit, or a dexterous Sophiſtication: And perhaps many Remedies, well deſigned by the Phyſician, have failed, or had miſchievous effects, upon this account.

19. This is propoſed as a ſhort intimation of the preſent State of Pharmacy in *England.* If the Art be found more perfect in other Nations, it may perhaps be chiefly owing to this, That their Phyſicians are well acquainted not only with the Theory, but alſo the Practice thereof; two things which ſhould never be ſeparated, as being in reality but one effective thing conſiſting of two parts; *viz.* previous Notion, and Execution.

20. What uſeful addition or reformation the *Materia medica* is capable of receiving, no one at

at preſent can ſay. If a ſtrict Enquiry were made, perhaps it might be found proper to throw out of our preſent Collection a conſiderable number of Materials, to make room for others of greater efficacy. But this is no work for private perſons. Our preſent buſineſs is to ſee whether any improvements may be made in the ways of preparing the common Medicines of the Shops.

21. And for the better regulating of our Enquiry, it may be of ſome ſervice to lay down two larger Obſervations; *viz.* (1) That the Deſign of Pharmacy is to ſeparate from Bodies the more medicinal parts with which they are naturally endowed; and, upon occaſion, to mix ſuch of them together as will beſt anſwer the curative intentions. All in the power of Art is only to ſeparate and mix, or differently modify; 'tis Nature alone that is able to produce. Pharmacy therefore conſiſts in *Analyſis* and *Syntheſis* *.

*Deſign of Pharmacy.*

*Rules.*

22. (2) As it is the Perfection of Art to copy Nature juſtly; ſo, by reſolving Bodies into their Principles, we obtain a general Rule for Compoſition, and ſee the ſeveral Steps we ought to take in it. Nature ſhews us, that in all mixed Bodies there is a Baſis, or *Subſtratum*; ſomething to ſupport and envelope the other Ingredients. The natural Salts are thus diluted with Water; the Oils with both; and all together compoſe one uniform and elegant Whole. To preſcribe juſtly therefore, we ſhould imitate Nature: But if we compound without regard to this Rule, the Ingredients will appear huddled together, as if it were by chance; and, inſtead

* See Lect. VIII. and IX.

inſtead of preſerving and aſſiſting, they will often clog, encumber, and deſtroy each other.

23. We now proceed to our Experiments; whereby we propoſe to illuſtrate and improve, (1) the common Method of diſtilling Simple-Waters; (2) the common Method of preparing Tinctures; (3) the Method of preparing Syrups; (4) the Method of making Electuaries; and (5) the Method of making compound Oils, Unguents, and Plaiſters: Thus propoſing to touch upon the chief Articles of the preſent *Galenical Pharmacy*, as it is vulgarly called; tho' in reality no leſs *chemical* than the other. *The Intent of the Experiments.*

## Experiment I.

### *The beſt Way of diſtilling Simple-Waters.*

24. We took as much dried Mint, cut ſmall, as filled two thirds of our Still; then adding a ſufficient quantity of Rain-Water, to make the Plant float commodiouſly, yet leaving a fourth of the Still empty, we digeſted a while with a gentle Heat; then worked the Still, drawing off only ſo long as the Water appeared thick or milky, and taſted rich and grateful; whereby we obtained a *Simple Mint-Water* in tolerable perfection. *Simple Waters, how diſtilled.*

25. This Experiment, with a few occaſional alterations, may ſhew a general Method of obtaining Simple Waters in their greateſt perfection. The Subjects beſt fitted for it are thoſe of the odorous, aromatic, and oily kind; tho' ſome others alſo may perhaps communicate particular Virtues to the Water: Among the fitteſt may, however, be reckoned, *Angelica*, *Anniſeed*, *Caulm*, *Calamint*, *Cinnamon*, *Cloves*, *Fennel*, *Hyſſop*, *Roſemary*, *Tanſey*, *Wormwood*, &c. but particularly *The Experiment extended.*

cularly Pepper-Mint, which affords an extrem
ly aromatic, pungent, and agreeable Wate
good againſt the Cholic, and many other Diſo
ders of the Stomach and Bowels; whence i
uſe, perhaps, is too little known.

*Cautions.* 26. It is a principal Caution in this Oper
tion, to remove the Receiver, before the mo
pellucid, acid, faint, and dead Water com
over; as it ſoon will do; and if ſuffered to m
among the reſt, is apt to ſpoil the whole,
giving it a vappid or faint taſte, and ſometimes
degree of acidity, or vitriolic ſtypticity, and
emetic virtue: For part of the eſſential Salt
the Plant, now riſing, uſually corrodes the Co
per Head of the Still, and carries over with
ſome particles of the Metal: Whence the
Waters ſhould either be diſtilled with a Gl
Head, or one of Pewter, or tinned Copper;
elſe the Operation ſhould be carefully watche
that the ſecond Running may not mix with t
firſt. The greater care ſhould here be take
becauſe ſome Patients, more particularly Ch
dren, and thoſe of a tender habit, have ſuffer
thro' a neglect herein; and been vomited, pu
ged, and griped by the uſe of a Simple Wat
contrary to the intention.

*Regulation.* 27. The Simple Waters diſtilled after t
manner of our preſent Experiment, may in n
ny caſes prove too ſtrong to be uſed alone; t
then it is eaſy to let them down with comm
diſtilled Water, to the proper ſtrength: A
this is, beyond all compariſon, better than
mix ſuch Waters with their own Faints, or
quor of the ſecond Running.

*Improve-ments.* 28. There are two Improvements that mig
be made in this Method of obtaining Sim
Waters: The firſt is, by means of Cohobati
and Digeſtion; the other, by means of a p
vi

vious Fermentation of the Plant. With regard to the firſt; If the Liquor remaining in the Still be expreſſed from the Herb, and returned, along with all the Water that came over, upon a freſh quantity of the ſame Subject, and they be digeſted together, in a gentle Heat, for two days, then diſtilled as before; the Water thus obtained will be much richer, and more efficacious, than the former: And if the ſame Proceſs be repeated two or three times, thoſe who have not tried would ſcarce imagine how rich a Simple Water may be thus procured. And this Method we would particularly recommend for making the Simple Water of Baulm, Elder-Flowers, Roſes, Camomile, and the like Subjects, but ſparingly furniſhed with eſſential Oils; for they otherwiſe make but indifferent Waters.

29. The other means of improving Simple Waters is by uſing a previous, imperfect Fermentation: This is performed by adding to the Plant and Water, put together, as in our preſent Experiment, a tenth or twelfth part of Sugar, or Honey, or elſe a fortieth part of Yeaſt; then ſetting the whole in a warm place, to ferment for two or three days only, ſo that the Herb may not fall to the bottom, nor the Fermentation be above half finiſhed; then the whole being committed to the Still, a Water may, at one Operation, be obtained extremely rich, or impregnated with the full virtue of the Plant. And thus may Simple Waters be made fit for long keeping without ſpoiling; the ſmall proportion of inflammable Spirit generated in the Fermentation, ſerving excellently to preſerve them. And theſe two Methods ſeem applicable to the improvement of all thoſe ſimple Waters commonly found in the Shops.

30. We

30. We ſhould next proceed to ſhew th Method of perfecting or improving Compoun Waters, if we had not already endeavoured t do it, in our *Lecture* upon Diſtillation, by a Example in *Citron-Water* *.

## EXPERIMENT II.

### *The beſt Way of making light Tinctures, and In fuſions.*

*Light Tinctures prepared.* 31. We took half an Ounce of the Rind c *Seville* Orange, ſhaved thin, half a Dram c Gentian-Root, thin ſliced, a Scruple of th Tops of *Roman* Wormwood, half a Dram c Cardamums, and half a Dram of Cochinea each of them lightly bruiſed: Theſe Ingredient we put to ſteep, for a night, in a Pint of *Frenc* Brandy, and filtred the Liquor the next morn ing.

*Regulation.* 32. This Experiment is general, and not per formed for its own ſake, but to ſhew the Metho of making all kinds of the lighter and finer Tinc tures and Infuſions without Fire; which woul here prove prejudicial. The Preparation it ſel is, however, a good Stomachic Bitter, of th ſame general nature with thoſe commonly ſol under the name of *Stoughton's Elixir*. The ex cellence of theſe Preparations depends not mor upon the choice and goodneſs of the Ingredients than upon the manner of their being infuſed For if ſuffered to remain too long in the Men ſtruum, or if Heat be uſed in extracting th Tincture, the groſs, terreſtrial, and nauſeou parts of the Ingredients will be fetched out and the Tincture thus be loaded with a heavy indo-

* See Lect. XIII. Exp. V.

ndolent Matter, of little virtue. But if the nfuſion be made in the cold, and the Liquor rained off ſoon, only the finer and more ſpiri- uous parts of the Ingredients will be imbibed y the Menſtruum; whence the Preparation will ot only taſte and ſmell more brisk and agree- ble, but alſo have a much greater virtue and fficacy. But if, thro' the ſhortneſs of their ontinuance in Infuſion, the Ingredients ſhould ot have ſufficiently impregnated the Liquor, he Method is to pour the Liquor again upon reſh Ingredients, and again to ſtrain it off, ithout letting it ſtay too long upon them, or eeling the heat of the Fire. And thus, by re- eated affuſions of the ſame impregnated Men- ruum upon freſh Ingredients, an Infuſion, or Tincture, may be obtained, of almoſt any de- ree of ſtrength, or richneſs, without containing he groſſer or more concretive parts of the In- redients, but only what may be called their ner Spirit, or Quinteſſence. And this is no nconſiderable Secret both in Chemiſtry and harmacy; and may deſerve the regard of thoſe ho deſire to procure the full virtues of the imples, unaltered in their nature, yet exalted, r concentrated to ſuch a degree, that a few poonfuls of the Liquor ſhall contain the Spirit, r Quinteſſence, of a Pound of a Plant. And his is an effect not to be expected from the Fire, hich almoſt conſtantly alters the nature of hings committed to it; nor could a valuable ſſence of Violets, Jaſmin, Lilies, Borrage-Flow- rs, and any Flower or Plant of an extremely ne odoriferous Spirit, be procured by Heat, s it readily may by ſteeping theſe Flowers in old Water, cold Vinegar, cold Wine, or the ke; and frequently pouring the Tincture upon freſh

freſh Flowers, till the Liquor becomes ſtrong impregnated.

33. Apothecaries uſually commit the ſam error in preparing the finer Tinctures, that the do in working their Cordial Waters; and both caſes ſaturate the Liquor with the groſſe more uſeleſs, and leſs ſpirituous, parts of th Ingredients; whence the Cordial Waters of th Shops too often abound with a groſs, heavy, di agreeable Oil; and the Tinctures of the Shop with a groſs, heavy, Earth, or kind of bitumi nous Matter, inſtead of a brisk, lively, and i vigorating Spirit; which alone is the thing re quired in both caſes.

34. This Doctrine of Tinctures and Infuſio ſhould be reduced to Rule, for the improveme of Chemiſtry; which will never be perfected t it can extract, ſeparate, and concentrate, th virtues of things unimpaired, or unaltered their nature. And doubtleſs it would prove very ſerviceable thing in Chemiſtry, Medicin and Natural Philoſophy, to know the beſt an eaſieſt ways of concentrating the virtues of Bodi unaltered: And this may, in ſome meaſur be effected by our preſent Method, and pra tiſed with well adapted Menſtruums: For, general, (1) a quick and cold Infuſion extrac the Spirit of Vegetables; but a long and h one confounds, impairs, or deſtroys it. (2) T repeat the Infuſion of a freſh Subject quick an cold in the ſame impregnated Menſtruum, ſeem greatly to collect and concentrate the Spir that is, the finer and more eſſential Part, Bodies. (3) The proper Menſtruums for th purpoſe ſeem to be ſuch as pure Rain-Wate Vinegar, Wine, Water mixed with a little fi Alcohol, Water and a little Sugar, and for ce tain uſes, the common atmoſpherical Air, whic

s an excellent Menſtruum to extract the Spirit r Effluvia of Plants, as we remarkably find n ſpicy Groves and Gardens; and may, in me caſes, be uſed with good effect.

35. But to obtain the ſaturated Tinctures of ard, reſinous, or gummy Bodies, requires a ifferent treatment, as in the following Experi- ent.

36. We took two Ounces of that hard *Indian* Roſin called *Gum Lac*, and reducing it into a ne Powder, made it into a kind of ſtiff Paſte ith Oil of Tartar, *per deliquium*; we ſet this aſte in an open Glaſs to dry, by a gentle eat; then removed it to the open Air, that might relent, or grow ſoft; and after this e dried it again, as before: And by repeating e Proceſs once or twice, the hard Body of the Roſin was at length reſolved into a purple-co- ured Liquor; which being now gently dried, nd reduced to Powder, afforded an excellent Tincture, by being boiled for two or three hours a tall Glaſs, with Alcohol. *Solution of Gum-Lac.*

37. This Proceſs is almoſt general, or may e advantageouſly uſed for making the Tinctures f *Myrrh*, *Gum-Juniper*, *Dragons-Blood*, *Amber*, nd other hard, gummy Subſtances; which will carce otherwiſe yield a Tincture in Spirit of Wine. Any improvement in the extracting Tinctures with Alcohol, may tend conſiderably o improve the Art of Pharmacy; becauſe ſuch Tinctures are generally found powerful Medi- ines; the Spirit of Wine appearing greatly to ncreaſe the virtue of the Subjects. Thus, tho' he Tincture of Amber prepared in this manner ppears to be only a bare ſolution of the Sub- tance of the Amber; yet it is found to have uch effects as are no way equalled by any fine owder of Amber: And what ſeems remark- able, *The Experiment extended.*

able, tho' ſo large a quantity of fixed Alkali b uſed in the Preparation of theſe Tinctures, ye they give no manifeſt ſigns of containing a Alkali; which is therefore changed in the Ope ration, whether by the Acid naturally contain ed in theſe reſinous and gummy Bodies, or b being expoſed to the Air, or both.

*Varied.* 38. There are other Methods of extracting the Tinctures of theſe hard, gummy Bodies but that delivered appears to be the beſt; tho it might perhaps be ſhortened, by uſing ſom proper intermediate Subſtance to divide th Particles of the Subject, ſo as that the alkalin Salt, the Air, and the ſpirituous Menſtruum might all come into fuller conſent therewith and act more forcibly thereon. And for thi purpoſe we would recommend pure virgin Earth ſuch as is commonly uſed for the making o Teſts or Cupels; by means whereof Spirit o Wine will extract a tolerable Tincture fro *Myrrh*, without the addition of any fixed Al kali.

39. But when Tinctures not ſpirituous, o only aqueous Solutions of theſe hard, gummy Bodies are required, we recommend the uſe o the ſoluble Tartar, or *Tartarum Tartarizatum* for a Solution of this Salt will readily diſſolve Myrrh, even in the cold; as Water diſſolves Gum-Arabic *.

## EXPERIMENT III.

### *The beſt Method of making Syrups.*

40. We took three Ounces of the yellow external Rind of freſh Oranges, and infuſed them in

* See Lect. XIII. Exp. V. § 47.

in a cloſe Veſſel, with a gentle Heat, *in Balneo Mariæ*, for ſix hours, along with a Pint and a half of pure Water; then ſuffering the Infuſion to cool, we filtred the Liquor; and, adding to it twice its own weight of hard Double-refined Sugar, made it into a Syrup, in a cloſe Veſſel, ſet *in Balneo Mariæ*. *Syrup of Oranges made.*

41. We could not contrive a general Example to fit all Syrups, becauſe they differ greatly in the Liquors of which they are made; or according as theſe Liquors are Infuſions, Decoctions, natural Juices, Wines, or Vinegars. We choſe to give an Inſtance in a Syrup made of a Liquor by the Infuſion of an aromatic Subſtance; whoſe Virtue would be almoſt intirely loſt, if the Syrup were to be prepared by long boiling, as it is ſometimes directed, with leſs than an equal weight of Sugar. Diſpenſatory-Writers have perhaps no where erred more remarkably than in directing the making of Syrups; which ſeems the more ſtrange, becauſe this part of Pharmacy is extremely facile: The misfortune ſeems to have lain, that great Men cannot ſubmit to conſider common and ordinary things; whence, however, the credit of a Phyſician may ſink in the eſteem of thoſe who by their employ are led to a knowledge of theſe ordinary things. *Uſes.*

42. We judge that the whole of this buſineſs may be reduced to a few eaſy Rules; which we ſhall here endeavour to lay down, for improving this Branch of Pharmacy. And (1) It is matter of Experience, that aqueous Infuſions, Decoctions, or other aqueous Liquors, require twice their own weight of dry Sugar-Candy, to make them into a Syrup of a juſt conſiſtence for keeping, without candying, or fermenting. This Rule, by directing the uſe of *Sugar-Candy*, ſeems to fix the conſiſtence of Syrups with exact- *Rules.*

a tall Glaſs in a Sand Heat, with ten Ounces of Water, and fourteen Ounces of Sugar, ſo as that nothing might evaporate, for two hours; then ſtraining and preſſing out the Syrup, we added to it an Ounce of freſh raſped Saſſafras, a Dram of Cinnamon, and ten Grains of Nutmeg, all reduced to fine Powder; and made the whole into an Electuary.

*Regulation.* 46. In the common Method of making this Electuary, the Saſſafras and Cinnamon are boiled in the Water, whereby a great part of their Virtue is loſt, or not extracted: Whence the Medicine comes to be defrauded of its due. But here, by boiling the Ingredients in a tall Glaſs, with a due proportion of Sugar and Water, to make a Syrup (allowing an extraordinary proportion of Water, for what the Saſſafras will drink up) we obtain the fine aromatic Virtues of the Ingredients to advantage, without any conſiderable loſs.

*Rules.* 47. To make Electuaries in perfection, where a Syrup is employed as their Baſis, (1) the Syrup ſhould be prepared in the manner above delivered *; ſo as that the Virtues of the Ingredients may be preſerved; (2) the Powders, or Species employed, ſhould be freſh and fine ground; (3) the Gums, where any are uſed, muſt be well cleanſed, and diſſolved in their proper Menſtruums; and (4) the whole muſt be mixed, or thoroughly united, into a ſmooth, uniform Subſtance, of a due conſiſtence for keeping, without either candying, or running into Fermentation.

48. (1) Where Syrups are uſed in the making of Electuaries, care is not only required that the Virtues of the Ingredients of the Syrups be pre-

* Exp. III.

preſerved as much as the form will allow of, but alſo that its conſiſtence be not too high; for this would diſpoſe it to candy in the Electuary, and render the Medicine unduly mixed, or knotty; the Sugar thus concreting together in lumps, or ſhooting away from the Species. Again; If the Syrup be made too thin, or aqueous, ſo as not to ſuſpend and hold the Powders together, by a binding Conſiſtence, the Syrup will of neceſſity ferment in hot weather, and become firſt ſomewhat vinous, afterwards ſour, or acetous, and at length corruptive *; ſo as to change, invert, or deſtroy the nature of the Medicine: For purgative Ingredients, by fermenting, loſe their purgative Virtues; and all other Ingredients, by corrupting, are reduced to an indolent kind of Fæces, or *Caput mortuum*, very different from the thing intended †. And hence Electuaries that have thus fermented, or changed their nature, may ſometimes prove pernicious, inſtead of ſalutary.

49. The Electuaries made with the Pulp of Fruits are leſs diſpoſed to keep, for any conſiderable time, perfect, on account of the greater tendency which ſuch pulpy Subſtances have to Fermentation and Putrefaction. Thus, tho' the *Lenitive Electuary* were made ever ſo artificially, it will ſcarce keep many months without altering its nature; but eſpecially if the Conſiſtence was originally too thin: Whence ſuch Electuaries ſhould be made in ſmall quantities, or freſh as they come to be wanted.

50. But this does not equally hold of the *capital Electuaries*, ſuch as *Venice-Treacle*, or *Mithridate*; which require to lie for ſome time, that the Ingredients may digeſt, or ripen, as it were,



* See Lect. X. *paſſim*. † See Lect. VII.

and grow mellow together; for the Gums and Spices that enter these Compositions preserve the Medicines from alterations for the worse, and the Mixture becomes more perfect by time; provided the Hony used in their Composition do not candy, or the whole become too dry. To keep the Hony from candying, some Artists mix the Spices and Gums with it unclarified; only taking care to separate the foul parts that lodge either at the top or bottom. And if the Medicines prove too dry, 'tis usual at any time to soften, or beat them up in a Mortar, with *Canary*: And thus these Capitals of the Shops are supposed to improve by keeping. But *Diacodium*, having few of the warm Gums in its Composition, is more apt to alter, and lose of its astringent or styptic quality by keeping: For which reason it seems an alteration here for the better, to use a quantity of *Saccharum rosatum* instead of Hony, or *Diacodium*; as this not only gives a greater compactness to the Medicine, but also contributes to preserve its Colour and Virtues.

51. (2) The Powders, or Species, that enter the Composition of Electuaries should be fresh, because they lose of their Virtue by keeping; and they should also be fine ground, because they would not otherwise intimately mix with the Hony or Syrup, nor so readily part with their Virtues in the Stomach, nor render the Medicine so agreeable to the eye. The common method of reducing these Powders to a sufficient degree of fineness, by the Mortar and Searce, is faulty; because this method exposes them too long to the Action of the open Air; whereby their more volatile and grateful parts are carried off, whilst only the grosser are left behind: Whence it might be proper to have a close

Engine

Engine contrived for the purpoſe, ſo as to prevent this ill effect.

52. Some Artiſts grind their Powders for Electuaries by means of a Horſe-Mill; but the Mill-Stones here wear off, and communicate a gritty or ſtony Matter to the Ingredients, ſo as to prove diſagreeable in the mouth, and ſomewhat increaſe the bulk of the Medicine, without adding to its Virtues. Nor is this method, by the Mill, free from the inconvenience of the Tartar; for the finer or more ſpirituous parts of the Ingredients alſo fly off; as is ſenſibly found by the whole neighbourhood where any large quantity of the Ingredients for *Venice-Treacle*, *&c.* is ground by the common Horſe-Mill. *Improvements.*

53. (3) The better way doubtleſs is, by the means of Iron Rollers, moving oppoſite to each other in a cloſe Box, to grind all the Ingredients, *viz.* the purified Gums, the Roots, Herbs, Flowers, *&c.* along with the Hony and Wine, after the manner of the new-invented *Chocolate-Engine*; for thus the fine, volatile, and aromatic parts of the Ingredients may, as well as the groſſer, be entangled with the Hony and Gums, and all at once be mixed uniformly together into a ſmooth Maſs of a due Conſiſtence.

54. (4) But perhaps a much better, though more troubleſome Method would be, in the form of Extracts, eſſential Oils, *&c.* to get out the full Virtues of the Ingredients, without any of their groſſer parts; and mix theſe Oils, Extracts, Gums, Roſins, *&c.* together, with a ſuitable proportion of Hony, *&c.* ſo as at once to perfect and concentrate the Medicine; which might therefore be given in Doſes of an agreeable ſmallneſs, with all the advantages that can well be expected. And the ſame Method ſeems alſo applicable to the making of *Pills* and *Troches*,

## EXPERIMENT V.

*The best Methods of making the compound Oils, Unguents, Cerates, and Plaisters.*

*Oils, or Liquid Balsams.* 55. We took twelve Ounces of fine Sallad-Oil, half a Pint of *Canary*-Wine, and half an Ounce of Dragons-Blood reduced to fine Powder; these we boiled together, over a gentle Fire, till the Wine was exhaled; and thus obtained a fine red Oil, or liquid Balsam. (2) To one half of this Oil we added four Ounces of yellow Bees-Wax, six Ounces of *Venice* Turpentine, and dissolved them together over the Fire; then removing the Vessel into the cold, we added half an Ounce of Balsam *Peru*; and thus made a red Ungent, or better sort of *Lucatellus*'s Balsam. (3) To the other half of the red Oil we added a due proportion of Wax; so as when cold to give it the consistence of a Cerate, or soft Plaister: And (4) By adding more Wax, and a proportion of Rosin, we made the Cerate into a Plaister of a hard consistence.

*Consistent Balsams.*

*Cerates.*

*Plaisters.*

*The Experiment extended.* 56. (1) This Experiment at once shews us the Method of preparing the compound Oils, Unguents, Cerates, and Plaisters. The making of compound Oils, in general, depends upon boiling certain Ingredients, as particularly recent Herbs, well bruised, or else their Juices, in Oil, till the aqueous moisture is exhaled (as the Wine was in the present Experiment) and the Plant become almost crisp; at which time the Vessel must be removed from the Fire, and the Oil squeezed from the Herb by means of a Skrew-Press.

*And applied.* 57. This Oil is now to be set over the Fire again, that its remaining aqueous moisture may exhale,

exhale, and the grosser parts of the whole subside; whereby the Oil will become not only more beautiful in Colour, but also more durable, or keep the better from turning mouldy. If the Pan be not removed from the Fire before the Herb is grown crisp, the Oil will be in danger of turning black, or being burnt; which both spoils the Colour, and gives a disagreeable Odour. If these Cautions are duly observed, the common compound Oils, by Decoction, may be obtained in their intended perfection; as Oil of Camomile, Elder, Roses, Earth-Worms, *&c.* And after the same manner are several compound Ointments made, by boiling Herbs along with Lard, or Suet; as the Ointment of Elder, Populeon, Nerve-Ointment, Mililet-Suet, *&c.*

58. The red Oil, obtained in the first step of our present Experiment, shews how liquid compound Balsams are procurable by dissolving resinous Gums in Oil, over the Fire. And in this manner a fine Balsam may be made with *Gum Elemi*, and tinged beautifully red with Dragons-Blood, or an Infusion of Alkanet-Root in Oil. And upon the same foundation might several excellent liquid Balsams be prepared, for chirurgical uses.

59. Powder of red Saunders has been commonly used, instead of Dragons-Blood, in the making of *Lucatellus*'s Balsam; but doubtless Dragons-Blood is much better suited to the intention of a Balsamic, a Healer, and Detergent; and also improves the Colour of the Medicine: Tho' red Saunders may be made to give a very good red Colour to the Balsam, by infusing the Powder cold for two or three days in White Wine; which opens the Body thereof, exalts the Colour, and renders it communicable with advantage to the unctuous Ingredients.

But

But this end may be more expeditiously answer by infusing a little Alkanet-Root in the Oil.

60. The Consistence of an Unguent is giv either by using animal Fats, as Lard and Su or by the addition of Wax, Rosin, Pitch, d Powders, metalline *Calces*, *&c.* and by addi a smaller or larger proportion of these solid dry Ingredients, we obtain the Consistence of Cerate, or Plaister, respectively. When ha animal Fats are used, the Process differs r from that for making the compound Oils where Wax, Rosin, *&c.* are employed, the m nagement is the same as in the present Expe ment, where the Consistence of the Oil is thic ened into that of a Balsam by Wax.

61. When dry Powders, or metalline Calc are used in the making of Ointments, the Po ders should be fresh and fine ground, and t metalline Calces made more subtile by Tritur after which the whole may be mixed smooth t gether, or beat up in a Mortar: And thus t *Unguentum album*, *Deficcativum rubrum*, *Diapo pholygos*, &c. are readily prepared.

62. The Plaisters made with metalline Calc such as *Diachylon*, and *de Minio*, require no W or Rosin to give them an emplastic Consistenc the bare Solution of the metalline Calces, or t Litharge, and Red Lead, in the Oil by boilin being sufficient for the purpose. Thus, if h a Pound of Red Lead, half a Pint of Vineg or Water, and twelve Ounces of Oil, be boil together, over a gentle Fire, with continual sti ring, till the aqueous moisture be consume and the Red Lead entirely dissolved; the Ma ter, when cold, will be of a hard, emplas Consistence, and differently coloured, or re brow

* See above § 55.

rown, or black, according as it was more or ſs boiled.

63. In the making of Plaiſters with metalline owders and Oils, it is always proper to add Vater, or other aqueous Liquor, to keep the Mixture from burning, or turning black, before he due Conſiſtence is gained, or the requiſite Diſſolution made. But here great care muſt be ad, not to throw in cold Water, if that added t firſt be exhaled before the Operation is finiſh-d; for this would be dangerous, by cauſing the Matter to crackle, fly about, and boil over with reat violence: But if the Water be added in he ſtate of boiling, it occaſions no tumult; and nay be thus uſed with ſafety.

64. When aromatic Species, native Balſams, r eſſential Oils, are ordered in Unguents or Plaiſters, care muſt be taken to add ſuch Ingre-dients towards the end of the Operation, when he Veſſel is removed from the Fire; becauſe he heat of boiling Oil, *&c.* would cauſe the ine aromatic or odoriferous parts of the Ingre-dients to exhale, and be loſt to the Unguent or Plaiſter. The ſame Caution ſhould be likewiſe extended to the *Cantharides*, uſed in the *Paſta epiſpaſtica*, &c. and to other Bodies of a delicate Texture, whoſe more efficacious parts are ex-haled by Heat. And by the due obſervation of theſe few Rules and Cautions, the common com-pound Oils, Unguents, Cerates, and Plaiſters, may be made in conſiderable perfection.

## AXIOMS and CANONS.

1. We learn from the preceding Enquiry, That ſome part of the Salts of Plants, as well as their Oils, will riſe by Diſtillation with Wa-ter, and give an acid or alkaline nature to the ſimple

ſimple Waters thus propoſed, according to t
nature of the Plant *.

2. That no ſimple Waters ſhould be diſtill
ſo low, as to bring over any remarkable ac
or alkaline Liquor from the Plant; for fear
miſchievous effects, or making ſuch Wate
prove emetic or purgative, contrary to the i
tention †.

3. That the Virtues of ſimple Waters chie
depend upon their containing the eſſential C
of the Plant ‡.

4. That there are two Methods of perfecti
ſimple Waters; *viz.* Cohobation, and Ferme
tation **.

5. That all Tinctures, and Infuſions, of I
gredients whoſe principal Virtues depend up
their lighter, or more ſubtile and ſpirituou
parts, ſhould not be made with Heat, but
the Cold ††.

6. That if ſuch Tinctures, or Infuſions,
required rich and ſtrong, they are to be mad
ſo, not by ſuffering the Menſtruum to remai
long upon the Ingredients, or by the uſe
Heat; but by adding freſh Ingredients ſever
times to the ſame Liquor; infuſing them quic
and each time keeping out the Ingredients tha
have once been uſed ‡‡.

7. That the Fire is apt to exhale, alter, c
conſume the more ſubtile and ſpirituous par
of Vegetables; and therefore unfit to be uſe
where theſe more delicate parts are required *.

8. That the Buſineſs of Infuſions, and Tinc
tures, may be greatly improved, by extractin
the efficacious, or more ſpirituous parts of Ve
getables, unaltered in their nature; yet con
centrated

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* Exp. I. † ib. ‡ ib. ** ib. †† Exp. II. ‡‡ ib. * ib.

entrated, or brought together, into a moderate ompaſs.

9. That rich Tinctures may be extracted, ith Spirit of Wine, from the hardeſt reſinous nd gummy Bodies hitherto known, by means f fixed Alkali properly applied *.

10. That even aqueous Solutions may be ade of the ſame kind of Bodies, by means of e *Tartarum tartarizatum*, or ſoluble Tartar †.

11. That the Ways in common uſe for the aking of Syrups, Electuaries, compound Oils, nd Plaiſters, are improveable by the obſervance f a few eaſy Rules **.

12. That, therefore, there are grounds to xpect ſome improvement of the common Phar- acy, upon the footing it now ſtands; or by arely perfecting the Methods of preparing the hop-Medicines in uſe, without either retrench- ng their number, introducing new ones, or re- ucing the Art to a greater Simplicity.

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* Exp. II. † ib. ** Exp. III. IV. V.

LECTURE

# LECTURE XVI.

## CONTAINING

## *Attempts for reducing* PHARMACY *to greater degree of Simplicity and Efficacy*

*The Subject.*

1. WE now proceed to consider ho Pharmacy may be reduced to Sim plicity; which in Arts appears t include Perfection.

*The Simplicity of Pharmacy.*

2. The Simplicity of Pharmacy seems to con sist in supplying a few powerful, parable, saf and agreeable Medicines, for the Cure of Di eases.

*The Fate of Medicines.*

3. Those versed in the History of Physic ob serve that Remedies have their Run, or Revo lutions of Fate and Fortune; many of the being highly esteemed, or magnified, for a sea son, and afterwards to be thrown aside and neg lected.

4. Not to mention the Medicines celebrate by the Ancients, there are numbers of othe which have had their Revolutions almost withi our own memory. The *Elixir Proprietatis* o *Paracelsus*, the *Liquid Laudanum* of *Helmont*, th *Sal volatile oleosum* of *Sylvius*, the *Aperitive Tinc ture* of *Mœbius* *, the *Antihectic* of *Poterius*, th *Aqua benedicta*, or *Vinum emeticum*, of *Rulandu* the *Bercardic Powder* of *Sennertus*, Ceruse of An timony, and many more, have been extrava gantl

* That is, Spirit of common Salt neutralized with Salt o Tartar, and tinged with Red Roses.

antly valued in their time; but are now ſunk n the eſteem of Phyſicians. And thus perhaps ur preſent Opiates, our Salt of Vipers, our earls, our Bezoar, our *Aurum fulminans*, &c. ay loſe their credit hereafter, or give way to thers of no greater efficacy.

5. If we enquire into the Cauſe of this Inſta- ility in Pharmacy; it does not appear owing o the Medicines themſelves, but rather to the nattention, Levity, and Raſhneſs of Men: In- ttention, in not ſufficiently regarding and diſ- inguiſhing between the kinds and differences f Diſtempers and Conſtitutions; Levity, in reſently changing one Medicine for another, f the expected effect is not ſoon procured; and Raſhneſs, in uſing ſuch Medicines as come re- ommended by incompetent judges, or unfair epreſenters. *Cauſe of their Fate.*

6. If the Cauſe were owing to any changes in he Medicines themſelves, we could have little opes of redreſſing the evil; but as it is owing o ourſelves, we are hence encouraged to look ut for a Remedy.

7. The art of forming a ſound judgment of he ſucceſs and virtues of Medicines, is ſo little nown, that the mind uſually fluctuates herein, s being deſtitute of a ſecure foundation; and onſequently is led by rumour, opinion, and xample, inſtead of the true light ariſing from areful obſervation, and well digeſted experience. Whence it frequently happens, that unlucky vents are attributed to uſeful Medicines; whilſt uch events were really owing to ſome other auſe. *Regulation.*

8. This Inattention is ſucceeded by Levity and Raſhneſs: For when a Medicine thus fails to nſwer the expectation conceived of it, 'tis uſual o reject it, with contempt, and immediately to

ſeize

ſeize, in its ſtead, the firſt new one that com ſtrongly and vehemently recommended; whi again, after trial, is frequently rejected in t ſame manner as the former. And thus the liv of Phyſicians are often ſpent in flying from o Medicine to another, without fixing upon tho that are ſtable, or ſuch whoſe virtues are du determined and aſcertained.

9. This perverſe temper, or ill habit of t mind, muſt therefore be cured; or elſe Phyſ cians will continue to fluctuate, and not brin Pharmacy to a ſtate of perfection.

10. The way of rectifying this ill habit, w apprehend, is to acquire a competency of ſoun and fundamental medicinal knowledge, by kee ing ſteady to the uſe of a few ſimple Medicines which are eaſily prepared, no way hazardou and yet powerful in their effects: And to ſhe the way of procuring a few ſuch Medicines, i the deſign of our preſent Lecture.

*Procedure.* 11. We judge that all Medicines are commo dioufly reducible to four general Claſſes; *viz Evacuants*, *Alterants*, *Strengtheners*, and *Quieters* For as all the Cauſes of Diſeaſes muſt regar either *Quantity*, *Quality*, or *Motion*, the Medi cines adapted to theſe Cauſes will be either *Eva cuants*, *Alterants*, *Augmenters*, or *Appeaſers* o motion in the Body.

12. It muſt, however, be obſerved, that un der each of theſe general tribes of Medicine there are ſome better adapted than others to the Diſeaſes of particular parts. Thus it is matter of obſervation, that Mercury particularly affect the ſalival Glands, Cantharides the Bladder, *&c.* all which Remedies are to be collected, as ſo many particular Inſtances, under our reſpective general Heads of Medicines. And by duly proceeding in this manner, it ſhould ſeem that

we

we might eaſily fix upon a ſmall Collection of Remedies, able, with a proper Regimen, to cure the ordinary Diſeaſes.

13. At leaſt, by throwing out of our preſent Collection ſuch as are certainly found to be of ſmall efficacy, or certainly dangerous, we might greatly retrench the preſent Set of *Officinals*, and bring the more ſerviceable of them within the compaſs of a *portable Cheſt*. And with this view we ſhall endeavour to point out ſome of the more efficacious, portable, ſafe, and agreeable Evacuants, Alterants, Strengtheners, and Quieters; all along fixing a mark upon thoſe which we take to be either unſafe or inſignificant.

14. Our firſt Experiment will ſhew a Method of procuring a ſafe Emetic; the ſecond will ſhew how to prepare a ſafe Purgative; the third how to prepare a ſafe Perſpirative; the fourth how to prepare a ſafe Alterant; the fifth how to prepare an innocent Strengthener; and the ſixth how to obtain a powerful Quieter, or Anodyne.

## Experiment I.

### *An eaſy and ſimple Method of obtaining a ſafe and gentle Emetic.*

*An Emetic prepared.*

15. Two Drams of the common white Ipecacuanha being reduced to fine Powder, and infuſed for two or three days in half a Pint of white *Lisbon* Wine, in the cold; if the clear Liquor be decanted, freſh Wine may be added to the remaining Powder, ſo as to extract all the virtue; it will thus yield to Wine in the cold.

*Uſes.*

16. This Infuſion of *Ipecacuanha* in Wine appears to be the moſt ſafe, gentle, and agreeable Emetic hitherto known: Whence it may in moſt caſes be properly ſubſtituted for the *Vinum benedictum*,

*dictum*, the *Tartarum emeticum*, and all the othe antimonial Emetics; which are attended wit some degree of virulency, and uncertainty i their operation.

*Ipecacuanha analyſed.*

17. The Ipecacuanha Root, upon a prope Analyſis, by means of Water and Spirit o Wine, is found to contain a direct ſaline an reſinous part; whereof the ſaline is the larger whence even an aqueous Infuſion of the Roo will largely extract its virtues: So that a ſtron White Wine ſeems a Menſtruum well adapte to the extraction both of its ſaline and reſinou parts, on account of the large proportion o Water, and a leſs of inflammable Spirit, tha it contains. Add to this, that Emetics, as wel as Purgatives, are found to act the freer, eaſie and quicker, when joined with Wine, or othe ſtrengthening ſpirituous Vehicle. However, af ter both Water and Spirit of Wine have ſucceſ ſively acted upon this Powder, it ſtill retain ſome virtue; ſo that its power is greateſt whe given in ſubſtance: Whence our preſent Me thod of extracting a Tincture from it with Wine only abates of its violence, and, in ſome mea ſure, moderates its operation; ſo as to fit it fo weak Conſtitutions, or render it almoſt univer ſally ſafe.

*Not improved by Chemiſtry.*

18. This Root may, therefore, paſs for one of thoſe Simples which is little or nothing improved by a chemical treatment; Nature ſupplying it almoſt ready prepared to our hands, ſo a to require no more than drying, and reduction to Powder; at moſt no more than a bare infuſion in Wine, to render it a ſafe Emetic.

*Farther Uſes.*

19. Now, being once poſſeſſed of ſuch an Emetic as this, which ſeems to include the excellencies of all thoſe of the ſame tribe; it is doubtleſs proper to practice the *method of Rejection*.

*tion* upon the reſt; or at leaſt to examine whether any of them deſerve to be retained, and kept in the Shops.

20. We above obſerved *, that the common antimonial Emetics, of which there is a great variety, are virulent, or in ſome degree poiſonous; and therefore not to be truſted, when ſafer can be procured to anſwer the end. 'Tis true, ſome Practitioners have ventured to give *Arſenic* itſelf, in the quantity of a few Grains, as an Emetic; and thus it ſometimes operates violently, after the manner of the emetic Preparations of Antimony, which are nearly allied thereto. But as we certainly know, by many fatal inſtances, that *Arſenic* is a virulent Poiſon, even in a ſmall Doſe; it may ſeem a kind of madneſs to uſe it as an Emetic, when Ipecacuanha is at hand. And the ſame is to be underſtood, tho' in a leſs degree, of the *Mercurius Vitæ*, Glaſs of Antimony, Antimony-Cups, the perpetual Pills, the Sulphurs of Antimony, and indeed all other draſtic Emetics; which have a direct virulent virtue, and, if given in too large a Doſe, produce poiſonous effects. And here we do not except *emetic Tartar* itſelf; which, unleſs prudently diluted with Wine, or ſome Cordial Water, is apt to prove not only uncertain and churliſh in its operation, but ſometimes virulent or poiſonous; eſpecially when exhibited in a dry form, as in that of Pills, Powder, or Bolus: For all antimonial, or other metalline Emetics, coming in a dry form into the Stomach, ſeem to lodge in its membranous Coats, and ſtimulate and corrode them; ſo as to occaſion Spaſms, Convulſions, *&c.* after the manner of *Poiſons*. *Poiſonous Emetics.*



* § 16.

*Regulation.* 21. And the Solutions of Vitriol, Verdigreaſe, and various Preparations of Copper, have been, and ſtill continue to be, uſed, as Emetics, and uſually operate quick; yet we cannot judge ſuch Preparations ſafe, or any way comparable to Ipecacuanha for ſafety. And even theſe cupreous Emetics, when given in a large Doſe, have a corroſive effect upon the membranous parts of the Stomach; ſo as to prove, in a leſs degree, poiſonous. And thus, if the whole tribe of Emetics were carefully examined, and their effects noted, from competent experience, we judge they would moſt of them be found unſafe, or dangerous; and conſequently deſerve to be baniſhed the Shops, as Emetics, whilſt their place may be ſo well ſupplied by *Ipecacuanha*. And this method of Examination and Rejection being duly practiſed, might, as we apprehend, thin our Shops, and reduce the bulk of our Pharmacopœia's, to the great advantage of Pharmacy and Medicine.

## EXPERIMENT II.

### *An eaſy Method of procuring a ſafe and effectual Purgative.*

*A Cathartic prepared.* 22. If in a Quart of *Dulwich*-Water we diſſolve an Ounce of fine Manna, and half an Ounce of black Tamarinds; then ſtrain off the Liquor clear; we ſhall obtain an agreeable purging Ptiſan, or cathartic Liquor, in a Doſe ſufficient for a full-grown perſon of an ordinary conſtitution; the whole being drank at ſeveral draughts, in the ſpace of about an hour and half, or two hours.

23. It appears to be matter of obſervation, that the common purging *mineral Waters* operate with

with more eaſe, gentleneſs, and ſafety, than almoſt any Cathartics of the Shops; and only require to be concentrated by boiling, or quickened, in ſome caſes, to prevent the trouble of taking two or three Quarts for a Doſe. Our preſent Experiment, therefore, ſhews the method of quickening theſe Waters, by the addition of innocent Purgatives; ſuch as are *Manna*, *Tamarinds*, *Epſom-Salt*, *Tartarum tartarizatum*, *Tartarum vitriolatum*, &c. *The mild Cathartic preferred.*

24. The Shops, and common Diſpenſatories, abound with purgative Medicines; many of them draſtic, or violent, and ſome of them virulent, or almoſt poiſonous; of which kinds we reckon *Roſin of Jalap*, *Elaterium*, *Scammony*, *Gamboge*, *Coloquitida*, *Aſarum*, &c. all which are of a cauſtic nature, when given crude and alone; ſo as to prove mortal in a large Doſe: Whence we apprehend that the crude and ſeparate uſe of all ſuch Purgatives ſhould be baniſhed; eſpecially as there are numerous inſtances of their deleterious and poiſonous effects, and as we are abundantly provided of ſafer and more gentle kinds; for example, *Rhubarb*, *Manna*, *Tamarinds*, *Caſſia*, *Cremor Tartar*, *Epſom-Salt*; and particularly the purging *mineral Waters*. Or if the uſe of the more violent purging Simples be ſtill retained, let them at leaſt be boiled in Water; which is a certain way of rendering them milder, and diſcharging a great part of their malignity. And for the purgative Roſins, particularly thoſe of Jalap and Scammony, we would recommend them to be ground fine, and beat into a Paſte, with twice or thrice their quantity of blanched Almonds; which, by their oily matter, diſſolve the Texture of theſe Roſins, and render them more ſafe and innocent *. *The violent to be rejected.* *Or rendered milder.*



* See below Exp. III.

25. But we do not apprehend that the Art of Medicine has any occaſion for thoſe violent Purgatives. Certainly violent Purgatives are ſeldom proper, and generally prejudicial. If the ſtronger be ever required, we would, inſtead of the former virulent kind, recommend the ſimple Powder of Jalap-Root; which is found to operate much more mildly, and with greater certainty and effect, than its Roſin, Tincture, or other chemical Preparations of the Root; which is alſo the caſe of *Mechoacan* and *Rhubarb*.

26. We deſire it may be remembered, that the deleterious or poiſonous nature of the violent Purgatives above mentioned is much greater in the Body than that of the poiſonous Emetics; doubtleſs becauſe ſome part of theſe Emetics is ſoon thrown up again by the Stomach; whereas the Purgatives deſcend to the Inteſtines, and mix with the Juices of the Body: Whence we have a ſtronger reaſon for rejecting the uſe of theſe virulent Purgatives, than the uſe of the virulent Emetics.

*Regulation.* 27. And thus we conceive the matter of Purgatives may be reduced to a tolerable degree of Simplicity; yet ſo as to leave variety enough for ſuiting the different Diſeaſes and Conſtitutions where Purging is required. The nature of our Deſign will only permit us to indicate, as we go along, the Heads of this general Enquiry into the means of reducing Pharmacy to an elegant and uſeful Simplicity; the Introduction whereof is not to be expected from private hands.

EXPERI

## Experiment III.

### *A facile and ſimple Method of preparing a ſafe and effectual Sudorific.*

28. If an Ounce of refined Camphire be beat, and ground, in a Marble Mortar, with two Ounces of blanched Almonds; the Camphire will be thus ſubtilly divided, and brought into an uniform Maſs, fit for the forming of Pills, Boluſes, *&c.* ſo as to be commodiouſly taken in the way of a Sudorific, Diſcutient, or Perſpirative Remedy; the Doſe whereof may be aſſigned betwixt the limits of three Grains and forty, or two Scruples. *A Sudorific prepared.*

29. Sudorific, Perſpirative, and Alexipharmic Medicines, make a large part of the common Diſpenſatories: We judge that their places may be advantageouſly ſupplied by a few powerful ones of approved virtues; among which we eſteem this of Camphire as a principal one, or at leaſt ſuperior to *Gaſcoign*'s Powder, *Lapis Contrayervæ*, *Bezoar*, &c. whoſe virtues at beſt appear to be ſmall. *Uſes.*

30. We are ſenſible that the virtues of Camphire are not univerſally agreed to by Phyſicians; ſome eſteeming it hot, and others cold; ſome of great, and others of little efficacy: But the caſe is not to be decided by authorities, but experience; which ſeems to declare, that Camphire is one of the moſt powerful, moſt immediate, and moſt innocent Perſpiratives, Sudorifics, and Alexipharmics hitherto known: For a large Doſe of it, ſuppoſe a Scruple, or more, tho' given, diſſolved in Spirit of Wine, to a healthy Perſon, does not increaſe the Pulſe, or excite a præternatural heat; but rather cauſes a remarkable coolneſs

coolneſs and compoſure, with a gentle Sweating, or increaſe of Perſpiration. So little have the virtues of this Medicine been underſtood; or ſo little can the virtues of Medicines be deduced from their apparent properties, or reaſoning *a priori!*

*Hiſtory of Drugs.*

31. The natural and medicinal Hiſtory of this Drug well deſerves to be traced: It appears to be an eſſential Oil, of peculiar properties; tho' ſome would have it a Roſin, and others a Gum. Certainly it ſtands alone, as a thing *ſui generis*; or a body wherein the nature of Roſins, Gums, and eſſential Oils, all meet in ſome degree. It is perhaps one of the moſt diſcutient and ſubtile Remedies hitherto diſcovered: Whence it proves highly anodyne, perſpirative, and preſervatory. And we judge, from certain obſervations and experiments, that if the full virtues of this Concrete, both internal and external, were ſufficiently known, it might ſupply the place of numerous other Drugs and Preparations, to the eaſe and advantage of Pharmacy.

*Farther Uſes.*

32. In particular, we would recommend this Medicine, to be uſed inſtead of the common ſudorific Decoctions of the Woods, in caſes both of the recent and inveterate *Lues Venerea:* It may alſo be advantageouſly mixed along with the Balſams, or fine Turpentines, commonly uſed at the cloſe of that Diſtemper. In ſhort, we recommend it in all inflammatory, putrid, peſtilential, and even maniacal, Diſeaſes. And whoever has the ſecret of prudently joining this ſimple Medicine along with Nitre, may, as we apprehend, perform Cures ſcarce to be expected from other Medicines frequently uſed for the ſame purpoſes.

EXPERI-

## Experiment IV.

### *An easy and simple Method of procuring a safe and powerful Alterant.*

33. If an Ounce of well purified Nitre, *An Alterant from Nitre.*
nd two Scruples of Cochineal in Powder, be
oiled in five or six Ounces of Water; and the
olution be filtred, and afterwards evaporated
o drineſs, keeping the matter ſtirring as it
hickens; a fine red or purple Powder will be
eft behind; that is, the Nitre will be thus diſ-
uiſed, and reduced to a form fit for taking in
he way of Bolus, Powder, Solution, with any
onvenient vehicle.

34. Nitre thus prepared, in order to conceal *Uſes.*
o common a thing, we judge to be an extremely
afe and uſeful Alterant, capable of produ-
ing conſiderable effects in the Body, without
auſing any diſturbance, or ſenſible evacua-
ion, unleſs in the way of a Diuretic; in which
eſpect it operates as an Evacuant.

35. It is remarkable of Nitre, that it may, *Virtues.*
with ſafety, be injected into the Blood. *Mal-*
*ighi* injected ſix Ounces of its Solution into the
ugular Vein of a Dog, without obſerving any
ther effect than its proving diuretic. It is far-
her obſervable of it, that it heightens the florid
olour of extravaſated Blood, and excellently
reſerves it from putrefaction; yet does not li-
quify freſh and warm Blood, as has been ima-
gined; but ſomewhat thickens it, almoſt in the
manner of a Mucilage: Which may give us the
hyſical reaſon of many of its effects in the Body;
s particularly its allaying Inflammations and
evers, its ſtopping Hæmorrhages, curing the
pitting of Blood, *&c.*

36. If

36. If the medicinal virtues of this ſimple Medicine were to be enumerated, as they ſtand confirmed by competent experience, perhaps they would prove more numerous than thoſe of almoſt any Medicine hitherto known. It has been found ſerviceable in the Stone, and Stoppages of Urine; in Deliriums, in malignant Fevers, in Diarrhoeas attending the confluent Small Pox, *&c.* ſo as to prove a kind of general Remedy. And as all theſe excellencies of the Medicine are joined with that deſirable property of being innocent, or ſcarce any way prejudicial to the Body; it may ſeem ſtrange that it ſhould be ſo little uſed, or that Medicines no way comparable to it ſhould be preferred before it.

*Whence diſeſteemed.*

37. Poſſibly the mixing of Nitre with other Medicines may have occaſioned its virtues to be leſs known, or obſerved: Perhaps that humour of changing Medicines, almoſt every day, may not have given it the opportunity of ſhewing itſelf; but chiefly that ſtrange method of jumbling many Simples together in one Medicine, ſeems to have prevented the due noting of the effects of this and other ſimple Remedies. We, therefore, wiſh that the *Medicinal Hiſtory of Nitre* were drawn up, with care and judgment; as being perſuaded, that both Pharmacy and Medicine might hence be reduced much nearer to ſimplicity and perfection than they are at preſent.

## EXPERIMENT V.

*An artificial Method of preparing a powerful and innocent Strengthener.*

38. We put half a Pound of the beſt *Peruvian* Bark, reduced to fine Powder, into a proper Glaſs, and poured upon it two Quarts of Spirit of

f Wine; then shaking them well together, set them to digest in a Sand-heat for two or three days, till the Spirit of Wine appeared of a deep red Colour, inclining to purple. We now strained the Tincture through a close linen, and committed the Fæces, at last, to the press. Then returning the Pressings, or remaining Powder, into the same Glass, we poured thereto two Quarts of strong White Wine, and again set the Matter to digest for two or three days; then strained as before. After this we put the two Liquors into a Glass Body, and distilled off a large part of the Spirit of Wine; then evaporating the remainder in a glazed Vessel, with care to keep the matter stirring, and washing down, with some of the Spirit of Wine, the resinous parts that adhered to the sides of the Vessel. When the matter began to grow thick, we added to it three Ounces of the Syrup of Orange-Peel; and thus brought the whole to the consistence of an Extract. *An essential Extract of the Bark.*

39. This method of extracting the virtues of the Bark is the invention of M. *Charas*; who experienced its success in a large practice for fifteen years; wherein he never found it fail him, for the cure of all sorts of Intermittents. We have ourselves also had a competent experience of its success; and found it answer better than any other preparation of the Bark we had seen: Whence we judge it the best manner hitherto known of preparing an Extract from the Bark, so as to render it more innocent and effectual. *Its History.*

40. The Process was formed upon this supposition, That the Bark contained a Rosin and a Salt for its principal component parts; to the extraction whereof the two Menstruums are well adapted. And, in effect, we find that Spirit of Wine does extract a kind of Rosin from the Bark; *Rationale.*

Bark; and Wine such a part as renders it able to cure some kinds of Intermittents in certain Constitutions: Whence these two Menstruums, doubtless, take up the more medicinal parts of this substance, leaving its more woody or chaffy parts behind; which probably occasions that stoppage and troublesome weight at the Stomach we often hear complained of after taking large quantities of the Bark in substance.

41. The two finer and more medicinal parts of the Bark being thus extracted, they are commodiously joined together again by the interposition of the Sugar contained in the Syrup; so as to form an elegant whole, that may be aromatized at pleasure with the essential Oil of Mint, Cinnamon, or Cloves.

*Regimen.* 42. The Dose, and Method of exhibiting this Preparation of the Bark, are the same as the common; and though a much larger Dose should be given, it has not been found to produce any ill effect. The use of this Medicine is also attended with a quicker recovery of the natural complexion, vigour, and freshness, than the use of the crude Bark. And as this Medicine appears to be thus rendered so powerful and innocent, perhaps it may be proper to try it also in some other weakening Distempers besides Intermitting Fevers.

*Elæosaccharums recommended.* 43. There are many other powerful and innocent Strengtheners, besides this Preparation of the Bark; among the principal whereof come the capital Aromatics, Cinnamon, Cloves, Nutmeg; or rather their essential Oils; which being made into *Elæosaccharums*, afford as potent Cordial Medicines, in a commodious form, as can well be expected. But if more compounded Medicines are required, we would recommend the use of a *compound Elæosaccharum*, consisting of

f a few ſelect aromatic Oils, and the richeſt Gums and Balſams, as one general Cordial, or ompound Strengthener. And ſuch a Medicine ight be eaſily contrived, that ſhould collect to itſelf, or concentrate, the Cordial Virtues iſperſed in ſeveral capital Ingredients. Thus r example; Camphire, Balſam *Peru*, Balm of *ilead*, the eſſential Oils of Cinnamon, *Lignum loes*, Myrrh, *&c.* are all homogeneous; and pable of being united either alone, or with pirit of Wine, or Sugar; ſo as to be given ith all deſirable advantages and convenience.

## Experiment VI.

### *A ready Method of procuring a ſafe Quieter, or Anodyne.*

44. We took half an Ounce of Opium, and ſolved it with a gentle heat five or ſix times its own quantity of fair Water; then ſtraining e ſolution, and exhaling away the ſuperfluous oiſture, in a temperate Sand-heat, we reduced e Matter to a dry Subſtance; which being ound in a Glaſs Mortar, with twice its own eight of hard Loaf-Sugar, ſeems to afford us e of the beſt or mildeſt Preparations of Opium; d may be given from one Grain to three or ur for a Doſe. *Opium prepared.*

45. By diſſolving the Opium in Water, we t rid of its more groſs and reſinous parts; hich are found much more pernicious than the ſt: And by dividing its parts afterwards, ith Sugar, we render the Medicine more uni- rm, reſoluble, and miſcible with the animal uids; and can thus the better adjuſt its Doſe. t ſtill this Medicine is not without ſome per- cious property; nor does there ſeem any way known *Uſes.*

known to render the uſe of Opium perfect ſafe and innocent in all Conſtitutions: For if large Doſe of it be given, it is apt to diſtur or cloud the Head, cauſe a Vertigo, Delirium or Convulſions; in particular, it proves preju dicial to the Stomach and Inteſtines, which is apt to inflame and ſphacelate; thus actin in ſome degrees, as a Poiſon: Whence a bett method of correcting it ſhould be endeavoure after, or a more innocent Remedy be uſed i its ſtead. A mixture of Nitre and Camphir we apprehend, may ſupply its place on mar occaſions, without any fear of danger or inco venience.

*Regulation of Pharmacy.*

46. Thus we have endeavoured to give a inſtance of a ſimple and ſafe Preparation in eac of the four general Tribes under which we con ceive all Medicines may be commodiouſly ran ged; *viz.* Evacuants, Alterants, Strengthener and Quieters. If the Method we have here ob ſerved were purſued to its due length, it migh doubtleſs, terminate in the certain diſcovery o a few ſimple, elegant, innocent, and powerfu Remedies; at leaſt it would enable us to thro out, as dangerous, noxious, or poiſonous, large part of our preſent *Materia medica*, an pharmaceutical Preparation; and a conſiderab part thereof, as almoſt uſeleſs, or inſignificant Whence ſome tolerable degree of perfection i Pharmacy might be obtained.

47. Thus all the Medicines that have Lea in their compoſition are ſcarce to be truſted fo internal uſe. We have various inſtances of th poiſonous nature of this Metal; as particularl among the Workmen at the White-Lead Houſe the Colourmen, or Grinders of Ceruſe, an thoſe who any way work in Lead. And it wer ſufficient to baniſh the frequent internal uſe o

*Saccha*

*Saccharum Saturni*, the *Tinctura antiphthiſica*, &c. o read, in the *Miſcellanea curioſa* *, how many Men were poiſoned by drinking of acid Wine endered ſweet with Litharge.

48. But Metals do not act in the Body, till hey are once diſſolved: Whence large quanti-ies of crude Mercury, being ſwallowed, prove armleſs, through the want of a Menſtruum in ne Stomach, *&c.* to diſſolve it. But when crude Mercury is diſſolved by its proper Menſtruum, s in the Preparation of Mercury-Sublimate, ve ſee it becomes one of the ſtrongeſt of Poi-ons. Lead, Iron, and Copper, being much more eaſily diſſolved than Quickſilver, are ſel-om taken without ſome remarkable effect; hich muſt neceſſarily prove the greater, the more of an acid, or, in the caſe of Copper, ven alkaline humour, is lodged in the Stomach, r Inteſtines: Whence we derive a phyſical rea-on why theſe Metals often produce different fects in different conſtitutions. The internal ſe of the *Cryſtals* of *Silver*, though ſometimes ucceſsfully given in dropſical caſes, ſhould ardly be truſted, on account of their corroſive crimony; which has ſometimes occaſioned loody Stools, and extreme weakneſs. The ommon Tinctures of Copper, and Solutions of ue Vitriol, can ſcarce be taken internally with fety; as being not only emetic, but in ſome egree corroſive and poiſonous. Even the *Au-m fulminans*, though highly eſteemed by ſome s an internal Medicine, cannot be ſafely given, nleſs it has been firſt well waſhed from its lts, and does not meet with a ſuitable acid lvent in the Stomach: For in both theſe caſes may have dire effects; of which there have been

* Decad. III. Obſ. 30.

been remarkable inſtances. Iron and Tin hav not been found ſo pernicious to the Body, bu rather beneficial; eſpecially Iron, when pru dently prepared and uſed. Indeed, of all th Metals, Iron ſeems to be the moſt innocent, an ſufficiently powerful, tho' diſſolved in ſo weak Menſtruum as Wine. And as this is the reſu of our method of Rejection, applied to Meta in metalline Preparations; ſo we apprehend th if the ſame method were applied to the whc *Materia medica*, there would thence reſult th diſcovery of ſuch ſafe and powerful Medicin for the Cure of all ordinary Diſeaſes: When we would recommend this kind of procedure thoſe who regard the improvement of Pharma and Phyſic.

## AXIOMS and CANONS.

1. We learn from the preceding Enquir That certain Simples are naturally better pr pared for medicinal uſe, than by the comm chemical treatment; ſuch in particular are Ip cacuanha, Jalap, Rhubarb, Mechoacan, & Tables, or Catalogues, of which kind of Simpl ought to be formed, in order to abridge an perfect Pharmacy*.

2. That moſt of the Emetics, in comm uſe, eſpecially the antimonial kind, are virulen and ſomewhat poiſonous, compared to th milder one of Ipecacuanha†.

3. That many of the common violent Purg tives are of an actually poiſonous nature; an therefore to be artificially corrected, or e more innocent kinds to be uſed in their ſtead particularly the purging *mineral Waters*, Mann Rhubarb, *&c.*

4. Th

* Exp I. † Exp. II.

4. That the more violent, and poisonous, Purgatives, such as Elaterium, Coloquintida, Scammony, Hellebore, *&c.* may have their poisonous quality mitigated, or taken away, by boiling in Water and other Expedients *.

5. That the effects of the poisonous Purgatives are proportionably greater in the Body than the effects of the poisonous Emetics †.

6. That the two principal Tribes of Evacuants, *viz.* Purgatives and Emetics, are reducible to a few simple and easy Preparations ‡.

7. That Camphire has considerable virtues, as a Perspirative, Sudorific, and Resolver; being capable of uniting with oily Substances, and bearing a relation to essential Oils, Rosins, Gums, and Balsams **.

8. That purified Nitre has many medicinal virtues; so as advantageously to supply the place of numerous other Medicines ††.

9. That this purified Nitre has a great power of preserving the Blood uncorrupted, fresh, and florid ‡‡.

10. That many of the medicinal virtues of Nitre do not depend upon its liquifying, but rather upon its jellying, the Blood *†.

11. That the Perfection of Physic and Pharmacy may have a considerable dependence upon the medicinal History of Nitre †*.

12. That the *Peruvian* Bark may be rendered more innocent and effectual than when given in Substance, for the Cure of Intermittents, *&c.* by means of a proper treatment, or by extracting and uniting its saline and resinous parts with a suitable intermediate Substance *.

13. That this Bark appears to contain three very different parts in a loose Texture; *viz.* a rosin, a salt, and a woody Substance †.



* Exp. II. † ib. ‡ Exp. I. III. ** Exp. III. †† Exp. IV. ‡‡ ib. *† ib. †* ib. * Exp. V. † ib.

14. That possibly the resinous and saline Extract of the Bark may be serviceable in curing more Diseases besides Intermitting Fevers; and that probably the frequent failure of the common Infusions and Extracts of this Drug are owing to their containing much of its resinous part without the saline one, or the saline part without much of the resinous; and not a due mixture and full proportion of the two, as they naturally abound in the Bark itself: Whence the Substance has been generally found more effectual than any of those imperfect Extracts, Tinctures, or Infusions †.

15. That powerful Strengtheners, or Cordials, are obtainable from a mixture of the richer Balsams, and essential vegetable Oils ‡.

16. That Opium may be so prepared as to become more innocent than in the common methods of treating it **.

17. That a less noxious Quieter is wanted than Opium; and may, in some measure, be supplied by Nitre and Camphire ††.

18. That no Preparation of Lead can be long or freely used internally, without considerable hazard ‡‡.

19. That the common Solutions and Preparations of Copper, Silver, Gold, and Mercury are hardly proper for internal use; nor even Tin and Iron, unless prudently prepared with gentle Menstruums, and cautiously given *†.

20. That there are rational grounds to expect some considerable Improvements in the present State of Pharmacy and Medicine, by a due Enquiry, and a proper use of the means conducive to this end †*.

† Exp. V. ‡ ib. ** Exp. VI. †† ib. ‡‡ ib. *† ib. †* See the whole Lecture, *passim*.

# LECTURE XVII.

CONTAINING

MINEROLOGY; *or the Art of Mining: With the previous Operations to* Metallurgy; viz. *Roasting, Stamping, Washing, and the Business of Fluxes.*

1. WE are now entering upon a large, and extremely useful, Branch of Chemistry; the Business of *Minerology* and *Metallurgy.* *The Subject.*

2. By *Minerology* we understand that previous part of Metallurgy, which teaches the ways of finding, judging, and digging of Mines; with the uses of Salts and Earths for the making of Fluxes, in order to the assaying and smelting of Ores, for their Metals. *Minerology, what.*

3. By *Metallurgy* we understand the performance of those several Operations required to separate Metals from their Ores, for the uses of Life. And according to this distinction we shall bestow one Lecture upon *Minerology*, and another upon *Metallurgy*, in the sense we have here explained them. *Metallurgy, what.*

4. *Minerology* is an Art that requires a considerable compass of knowledge, before it can be practised to advantage: For as this Art includes the discovery, sinking, and working of Mines; it requires a competent skill in the nature, effluvia, and effects of mineral matters, whether Earths, Salts, Sulphurs, Stones, Ores, Bitumens, *Requisites to Minerology.*

mens, Gems, or Metals. It likewiſe requires a knowledge of the internal ſtructure of the Earth, and its various *Strata*; with a competent skill in ſubterraneous Architecture, Menſuration, Hydraulics, Levelling, and Mechanics; without which we can never judge what Mountain, Plain, or Valley, is proper to be dug; in what manner to dig it; how to diſcharge the Water that may flow in upon the Works; how the Beds of Ore and Stone will dip, or run; how the various kinds of Earths, Marble, and other mineral or metallic Matters, are to be cut through, or broken; or how the general Proceſs of Mining ſhould be conducted, in order to procure, with the leaſt expence, or bring to open day, the principal Matter or Ore required.

*Qualifications of a Metalliſt.*

5. And even when all theſe difficulties are conquered, no more than half the work is effected; and the end can ſtill be never obtained, without a tolerably exact knowledge of ſeveral chemical Operations; *viz.* Trituration, Torrefaction, Lotion, Calcination, Cementation, Fuſion, Amalgamation, Vitrification, Sublimation, Diſtillation, and the like: Whence it might be laid down as a Rule, That every directing Metalliſt ſhould not only be tolerably verſed in the ſeveral parts of Natural Philoſophy, but particularly be well acquainted with *Chemiſtry*.

6. And perhaps it may not be improper to intimate, that many metallurgical attempts have miſcarried, merely for want of a competent skill to conduct them. The under workmen in this way are generally a head-ſtrong, ignorant people, that cannot be managed without the uſe of ſome good political Rules, and a knowledge much ſuperior to their own. Yet how little ſoever the Art of Minerology may have been under-

underſtood, Hiſtory affords us numerous examples of plentiful fortunes and immenſe treaſures raiſed from Mines, as well by private perſons, as particular States and Kingdoms. But the vulgar, and even Philoſophers unverſed in Trade, generally eſteem the buſineſs of Mining precarious, uncertain, and unproſperous; eſpecially when compared with Agriculture, or other Arts, exerciſed more in the open day. *The Succeſs of Mining.*

7. The truth is; Mines are liable to many contingencies; being ſometimes poor, ſometimes ſoon exhauſtible, ſometimes ſubject to be drowned, eſpecially when deep, and ſometimes hard to trace. Yet there are many inſtances of Mines proving highly advantageous for hundreds of years: The Mines of *Potoſi* are, to this day, worked with nearly the ſame ſucceſs at firſt: The Gold Mines of *Cremnitz* have been worked almoſt theſe thouſand years; and our *Corniſh* Tin-Mines are extremely ancient. In general, the profit of Mines, compared with that of Agriculture, is immenſely greater in the ſame time, ſo as to compenſate largely for their want of certainty. Even Lead-Mines generally yield twice or thrice the returns of the richeſt Soils, improved in the ordinary manner, either by Nature or Art. What then ſhall we ſay of the Mines that are rich in the nobler Metals? The neat profit of the Silver alone, dug in the *Miſnian* Silver-Mines of *Saxony*, in the ſpace of eight years, is computed at a Thouſand ſix hundred and forty four Millions; beſides ſeventy three Tons of Gold *. *The Profit of Mines.*

8. Many Mines have been diſcovered by accident: A Torrent firſt laid open a rich Vein of the Silver-Mine at *Friberg* in *Germany*. Some- *Accidental Diſcoveries of Mines.*



* See *Petr. Albin. in Chronic. Miſn. Miner. German.*

times a violent Wind, by blowing up Trees, or overturning the parts of Rocks, has discovered a Mine. The same has happened by violent Showers, Earthquakes, Thunder, the firing of Woods, or even the Stroke of a Plough-Share, or a Horse's Hoof.

*The Art of Mining.*

9. The Art of Mining does not wait for these favourable accidents; but directly goes upon the search and discovery of such mineral Veins, Ores, or Sands, as may be worth the working for Metal.

*How to be practised.*

10. The artificial investigation and discovery of Mines depends upon a particular sagacity, or acquired habit of judging, from particular signs, that metallic matters are contained in certain parts of the Earth, not far below its surface.

*Signs of a Mine.*

11. The principal signs of a latent metallic Vein seem reducible to general Heads; such as (1) the discovery of certain mineral Waters; (2) the discolouration of the Trees or Grass of a place; (3) the finding of pieces of Ore on the surface of the Ground; (4) the rise of warm Exhalations; (5) the finding of metallic Sands and the like: All which are so many encouragements for making a stricter search near the places where any thing of this kind appears. Whence Rules of Practice might be formed for reducing this Art to a greater certainty.

*The Art of Boring.*

12. But when no evident signs of a Mine appear, the skilful Mineralist usually bores into the Earth in such places as, from some analogy of knowledge, gained by experience (or by observing the situation, course, or nature of other Mines) he judges may contain Metal.

13. This method of Boring consists in the use of a set of Scooping-Irons, made with joints, so as to be lengthened at pleasure; and thrust down to a considerable depth below the surface of the Earth

Earth, ſo as when taken out again to bring back ſamples of the Earth, or mineral Matter, from the depth whereto the Iron deſcended; much after the manner that ſamples of Sugar are taken by the inſtrument called a *Reſt* out of the Hogſhead.

14. After a Mine is found, the next thing to be conſidered is, whether it may be dug to advantage. In order to determine this, we are duly to weigh the nature of the place, and its ſituation, as to Wood, Water, Carriage, Healthineſs, and the like; and compare the reſult with the richneſs of the Ore, the charge of Digging, Stamping, Waſhing, and Smelting. This is a matter of common, civil, or oeconomical prudence. *When Mines may be dug to advantage.*

15. Particularly the form and ſituation of the ſpot ſhould be well conſidered. A Mine muſt either happen (1) in a Mountain, (2) in a Hill, (3) in a Valley, or (4) in a Flat. But Mountains and Hills are dug with much greater eaſe and convenience; chiefly becauſe the *Drains* and *Burrows*, as the Miners call them, that is, the *Adits*, or *Avenues*, may be here readily cut, both to drain off the Water, and to form Gang-ways, for bringing out the Lead, or Ore, *&c.*

16. In all the four caſes*, we are to look out for the Veins, which the Rains, or other accidental things, may have laid bare; and if ſuch a Vein be found, it may often be proper to open the Mine in that place; eſpecially if the Vein proves tolerably large and rich: Otherwiſe the moſt commodious place, for ſituation, is to be choſe for the purpoſe; *viz.* neither on a Flat, nor on the tops of Mountains, but on the ſides: For the Mineraliſt is always to exerciſe his judgment *Mines, where to be opened.*



* See § 15.

in the due choice of a place to begin the work.

*The beſt Situation of a Mine.*

17. The beſt Situation for a Mine is a mountanous, woody, wholſome ſpot, of a ſafe, eaſy aſcent; and bordering upon a navigable River. And ſuch a place as this being the ſtandard of goodneſs, all others may be judged of as they approach to, or recede from it.

*Requires Wood.*

18. Wood is indiſpenſably neceſſary for making the neceſſary Inſtruments, Engines, and Huts; as alſo for fencing the Pits, or Avenues, and ſupporting the Rock, where large Caverns are made, by digging away the Ore: And again, for ſupplying Fewel to the melting Works; unleſs where Pit-Coal will ſerve the turn. But though no Wood or Coal ſhould grow upon the ſpot, it may often be ſupplied by means of a navigable River, or cheap Carriage. And thus there are ſome rich Mines, in the hotter Climates, without ſo much as a Shrub growing near them.

*Water.*

19. Plenty of Water ſhould never be wanting; and is beſt ſupplied by a River; whence it may be commodiouſly derived, by Pipes, into the Lavadero's, Smelting-Huts, *&c.* or even brought into the Burrows themſelves, and made to work the ſubterraneous Machines. Theſe are conveniencies not to be expected from caſual Rains, or the Torrents of the Mountains.

*Good Roads.*

20. The Roads and Conveniencies of Carriage, to and from the adjacent parts, muſt be likewiſe regarded; as well for the ſale of the Metal produced, as the conveyance of Goods, and the neceſſaries of Life to the Workmen: For it rarely happens that Proviſions are afforded upon the ſpot where Metals are found.

21. The places abounding with Mines are generally healthy; as ſtanding high, and every way

way expoſed to the Air: Yet ſome places, where Mines are found, prove poiſonous; and can, upon no account, be dug, though ever ſo rich. The way of examining a ſuſpected place of this kind is, to make experiments upon Brutes, by expoſing them to the Effluvia or Exhalations, to find the effect. *And whol-ſome Air.*

22. But a conſiderable advantage may ſometimes be made, without the labour and expence of Digging: For as Springs and Rivulets are frequently the outlets of Mines, it may happen that the Sand of ſuch Waters ſhall be worth the waſhing for Metal; in which manner large quantities of Gold-Duſt are often procured. And hence it appears to be, that the Sands of many rapid Rivers contain Gold; and even the Sand of the Sea, in ſome places; though the latter in ſo ſmall a proportion as ſeldom to be worth the waſhing. But the Sand of ſuch Rivers wherein ſtamped Ores are continually waſhed may frequently deſerve to be aſſayed. *Metals obtainable without Mining.*

23. The Veins of a Mine greatly differ from each other, in depth, length, and breadth. Some ſtretch obliquely from the ſurface towards the central parts of the Earth; and theſe are called *deep Veins:* Others lie ſhallow and circular, ſo as to encompaſs a large ſpace; theſe are termed *ſpreading Veins:* Others poſſeſs a great part of the ſpace they lie in, both in length and breadth; and theſe are called *accumulated Veins*; being no more than a ſpace poſſeſſed by a group of Foſſils of one certain kind. But to give the Hiſtory of Veins, and Fibres, which are ſmaller Veins, their differences, their directions, their interſections, their different goodneſs, their diſcontinuations, their riſing, falling, *&c.* would be a large work. Let it, however, be obſerved, that theſe things ſeem *The different Veins.*

to

to proceed in a certain order; though the Laws of them have not been well obſerved, ſo as to afford the ſure Rules of Practice: Whence it ſometimes happens, that after a Vein has been ſucceſsfully traced for ſome time, it dips, breaks off, or takes a different courſe, leaving the Workmen as it were at fault.

*How to be traced.* 24. When a Vein of Ore is found, and all things prepared for the Work; if the Vein be of the deep kind *, it is firſt to be laid bare, and a Pit to be ſunk upon it; at the mouth whereof a Shed is to be raiſed, and a Crane, or Barre and Winch, fixed, for craning up the Ore. The Pit is to be ſunk either perpendicular or oblique according as the Vein happens to run.

*And dug.* 25. It is alſo uſual, in this caſe, to cut a Burrow, or Adit into the ſide of the Hill. This Burrow is uſually cut twice as high as wide, that the Workmen may commodiouſly paſs along it with their Barrows and Burdens; being for that purpoſe uſually about ſeven foot and a half high, and almoſt four foot wide. If this Side-Pit reaches to the firſt Pit, it becomes a true Burrow, open at both ends; and thus renders the work more facile and commodious, as the Ore may be now wheeled out in Barrows, inſtead of being craned up to the mouth of the Pit. After the ſame manner it is uſual to dig many Caverns into the ſides of the Mountain, in order to ſcoop out the Ore: So that ſometimes there are thus ſeveral Burrows made, to the eaſe and advantage of the work.

*The Burrows, how made.*

*The Digging various.*

*By the Spade.* 26. The Art of Digging the Veins varies according to the nature of the Vein; or according as it ſoft or hard. The ſoft Vein is generally dug with the Spade, and turned out into wooden

* See above § 23.

wooden Trays, placed underneath to receive it: But the hard Veins are knocked out with a Gad, or kind of Chizzel, and Hammer. But the Ore is ſo hard as to be incapable of breaking in this manner; they uſually ſoften it with Fire; which has the power of rendering the hardeſt and moſt flinty Stones brittle and friable. But a ſtill more expeditious method is the working with Gunpowder; by means whereof much of the hardeſt Rock may be ſhivered and ſplit in a very little time; a ſmall parcel of Powder being laid in a long Hollow cut for the purpoſe, after the nature of Gun-Barrel, and fired as it were at a Touch-hole; a ſmall vent, where the Quick-match is applied, being left for the purpoſe, and the whole Orifice being otherwiſe hard ſtopped up with Clay.

*By the Gad.*

*By Fire.*

*By Blaſting.*

27. The manner of purſuing and digging all ſorts of Veins, the ways of under-propping, and diſcharging the Water from the Works, the ſinking of Air-ſhafts, curing of Damps, and the like, we have not time to deſcribe *; our more immediate buſineſs being the treatment of the Ore, after it is dug and brought to open day: For which purpoſe there are certain previous Operations required, whereof we propoſe to exhibit Examples. Our *firſt* Experiment, therefore, will ſhew the method of Roaſting ſulphureous or arſenical Ores; the *ſecond* will ſhew the method of Stamping and Waſhing of Ores; and the *third*, the method of preparing Fluxes.

*The Deſign of the following Experiments.*

EXPERI-

* See *Agricola De re metallica.*

## EXPERIMENT I.

### *The Method of Roasting of Ores.*

*...dic roasted.*

28. We took a Pound of the common *Corniſ.* Mundic, and breaking it into ſmall lumps, ex poſed it upon the Grate of a Furnace, whilſt th Fire was made below; and thus at firſt gentl heated and torrified the Mundic; but after wards by degrees increaſed the Fire, ſo as t make the lumps glow, or appear red hot: I which ſtate we kept them for half an hour, o till no more ſulphureous Vapour or Stench roſ from them.

*The Experiment explained.*

29. This Experiment ſhews the common me thod of Roaſting of Ores, in order to diſcharg their ſulphureous, arſenical, or antimonial parts that might otherwiſe hinder their Fuſion, o elſe carry off a conſiderable proportion of th truly metallic Matter in melting. For fea this metallic Matter ſhould fly off, we made th Fire gentle at firſt; but increaſed it, by degree till the lumps became red hot; otherwiſe th Sulphur would not quit its hold; for Sulphu requires a naked Fire, and the aſſiſtance of th open Air, before it will burn, or go entire ly off*.

*And applied, to the kindly Ores.*

30. The richer and more tractable Ores hav no occaſion to undergo this previous operatio of Roaſting; but are uſually committed to Fu ſion ſoon after being dug up, and ſeparated fron their Stone, or Mine. However, if they con tain any conſiderable quantity of Sulphur, o Arſenic, 'tis uſual to roaſt even theſe a little.

31. Bu

* See Lect. II. *paſſim.*

31. But ſome Copper Ores are ſo ſtubborn and refractory, or hold their Sulphur ſo tenaciouſly, as to require many Roaſtings before they will let it go; being either ſtamped or melted after every operation; ſo that all the parts may, at ſeveral times, be equally expoſed to the Fire, and have their Sulphur diſcharged. *To the more ſtubborn Ores.*

32. In the large way of buſineſs this operation is uſually performed in a Trench cut ſomewhat aſlope on the Ground, that the Air may have the freer acceſs at the bottom; then they place a Layer of Billet-Wood in the Trench; and upon this a Layer of the Ore, in little lumps; and ſo continue, interpoſing a Layer of Wood and a Layer of Ore, for three or four ſtories; when the Pile being compleated, they ſet fire thereto, and make it continue to burn ſlowly for ſeveral days together; during which time there riſes a large quantity of ſulphureous Vapour, that may be perceived to a conſiderable diſtance. *In the large Way.*

33. But when the Ore, by repeated Roaſting, Stamping, and Fuſing, is become tolerably pure, they now finiſh the operation, by throwing it into a particular Furnace, having a Funnel to increaſe the draught; ſo as to make the Fire the ſtronger, and diſcharge the ſulphureous Fumes in greater plenty. And this Furnace is ſo contrived, that the open Flame of the Wood may play directly upon the Ore; whence all its volatile part is ſeparated, and the remainder left fit for the laſt Stamping and Waſhing.

34. When the Ores contain a large quantity of Sulphur, this uſually ſweats out and runs down into cavities made on purpoſe to receive it; whence it may be ladled out, and caſt into Moulds. But perhaps the moſt frugal method of Roaſting Ores, ſo as to ſave, or collect, all the *The Sulphur, how collected.*

the Sulphur, or Arſenic, they contain, is nc generally known and practiſed: For in the com mon way, a large proportion is loſt, whic might be collected by means of a proper Hooc in the form of Flowers; and alſo the riſing Fum might, by a particular ſtructure of the Furnac be made to paſs into a large Veſſel of cold Wa ter, and there be condenſed; as we ſee in cer tain chemical Diſtillations and Sublimations.

*Vitriol obtainable in the waſhing.*

35. After the poorer and more ſtubborn ſor of Copper-Ore have been thus ſucceſſively roaſ ed, and come to be quenched in Water, waſhed, they often impregnate the Water wit a vitriolic Matter; ſo that ſometimes profit ma be made by evaporating theſe Waters, and ſu fering the Vitriol to ſhoot: For the acid part the Sulphur, here ſeparated by the Fire, greatly diſpoſed to enter the metallic part the Ore, and diſſolve it; ſo as to form an actu blue Vitriol, or Vitriol of Copper; which ſel for a conſiderable price.

*Roaſting ſeverally profitable.*

36. And here it ſhould be remembered, th Ores rarely yield the leſs Metal for Roaſting unleſs the Fire were made too ſtrong, eſpecial at the firſt: For when the Yield proves ſma the general complaint of the Smelters is, Th the Ore, when ſent to their Furnace, was tc little roaſted; though indeed the fault is oft their own, in neglecting to make the Fire ſuf ciently briſk and ſtrong from the firſt; which a very conſiderable Secret for increaſing t Yield of an Ore.

*Tho' not always in imperfect Ores.*

37. There are, however, ſome reaſons to b lieve, that many imperfect Ores loſe conſider bly of their Metal by Roaſting; eſpecially wh they are mixed with arſenical, or antimoni Matters; which have a known property of vol tizing the impurer Metals, and carrying the

off in Fume: Whence, doubtleſs, it is, that ſome poor Ores and Mundics are commonly treated with little ſucceſs.

38. The Remedy in this caſe we apprehend to be the due uſe and application of ſome *fixing Subſtances*, whether of an abſorbent, alkaline, or neutral nature; ſuch as Quicklime, Kelp, or Pot-Aſh, dry River-Mud, Clay, Iron-Filings, or the like, mixed or ſtratified along with the Ore. And by certain additions of this kind, we doubt not but the Yield of ſome poorer Ores might be conſiderably increaſed. *This Inconvenience remedied.*

39. The buſineſs of Roaſting of Ores may be improved, and reduced to a few eaſy Rules. (1) We ſee it is of two kinds, or ſimple and compound; that is, either with or without addition. No addition is wanted when the Ore proves rich, or in itſelf nearly of a metallic nature; as ſome Ores are found to be. But additions are principally required, when arſenical, antimonial, or ſulphureous Matters are naturally mixed with the Ores. *Roaſting reduced to Rule; with regard to Additions.*

40. (2) The Fire is to be ſo regulated, from the firſt, that only the lighter, or more volatile, ſulphureous, or arſenical Fumes may go off; otherwiſe the more metallic part alſo would fly away, and, without ſome proper contrivance to catch it, be loſt. Yet the Ore muſt feel the force of an open Flame at laſt; otherwiſe all the Sulphur, Arſenic, Antimony, and other immature mineral Subſtances, will not be diſlodged. *The Fire.*

41. (3) The more theſe immature Subſtances abound in the Ore, the gentler the Fire ſhould be at firſt; and when the greater part of them is thus exhaled, the Fire is to be quickened by a freer admiſſion of the external Air.

42. (4) Laſtly; Where ſuch additions are uſed as are not metalline, for example, Lime, Mud,

Mud, &c. they ought to be ſeparated by Stamp
*And Waſhing.* ing and Waſhing, before the Infuſion, whic
would otherwiſe be hindered, or uſeleſsly encum
bered.

## EXPERIMENT II.

### *The Method of Stamping and Waſhing of Ores.*

*Mundic ſtamped and waſhed.* 43. We took the Mundic roaſted in our for
mer Experiment, and beat it fine in a metallin
Mortar; then ſearced it; and now putting
into a Buddling-Diſh, we waſhed it in ſever
Waters, with care to ſeparate the heavier po
tion from the lighter, and drying this heavie
part, which is always the more metallic.

*Waſhing and Stamping not always neceſſary.* 44. Theſe operations of Stamping and Waſh
ing are not neceſſary in the richer ſorts of Ores
but ſometimes abſolutely required in the poore
and more flinty kinds. If a large quantity
mere ſtony matter adheres to the Ore, it is ſome
times knocked off with Hammers; ſo as to leav
the more metallic part free from this barren
ſuperfluous Subſtance.

*Hard Ores, how ſoftened.* 45. If ſtill the Ore proves hard and flinty,
is ſometimes ſoftened by lying, for ſever
months, expoſed to the open Air; which th
renders it fit for the Stampers: Though it ſome
times alſo requires to be heated, or ignited, an
quenched in Water, to fit it for that purpoſ
Thus a large heap of hard, and otherwiſe un
tractable, Ore may be heated red hot, by inte
ſperſing it with Billets, and ſetting them
fire; after which it may readily be quenche
and rendered friable, by throwing cold Wat
upon it, or by deriving and paſſing a ſma
Stream of Water through it, from ſome adj
cent River. And ſometimes this operation

require

required to be repeated, before the Ore will grow ſoft and tractable.

*Ores how beſt ſtamped in the large way.*

46. It is uſual to ſtamp moſt Ores in a ſtate of moiſture, or wetneſs, to prevent the avolation of their Duſt, or Powder; but eſpecially ſuch as require much waſhing to ſeparate their barren and lighter earthy parts; which would otherwiſe uſeleſsly encumber the melting Furnace. To perform this Stamping the more commodiouſly, a Stream of Water is made to paſs under the Stampers; ſo as to make various windings and turnings, and, in part, run into certain cavities, made on purpoſe to catch and detain the heavier matter, whilſt the lighter is waſhed away to a greater diſtance by the Current.

*The Ores of the nobler Metals how waſhed.*

47. But the method of waſhing the Ores of the nobler Metals is more exact and curious; particularly in waſhing of Sand for Gold, on the Banks of the *Rhine* and *Danube*, where Gold is frequently found; eſpecially in ſuch places where the Sands are raiſed into large Heaps, or a kind of Mountains, by the rapidity of the Stream.

*Fine Gold Sand how waſhed.*

48. Theſe Sands are uſually waſhed, by the hand, in a particular long Trough, made with a Deſcent or Current for the purpoſe, and lined at the bottom with Flannel; for thus the Sand being artificially agitated with the hand, the lighter and larger ſtony matter riſes uppermoſt, whilſt the heavier deſcends, and is catched in the Pores of the woolly Cloth at the bottom: In the mean time the lighter matters are waſhed farther off by a Stream running down the declivity. And when the Flannel has thus collected a conſiderable quantity of the richer metallic matter, the whole Cloth may be eaſily taken off, and rinſed in a proper Veſſel of Water, where

all the metallic matter, before adhering to it, readily falls off, and sinks to the bottom of the Vessel; where, the Water being decanted, the Metal may be collected alone, and dried. And this is the method of procuring the Gold where the Sand is fine, or extremely small.

*The coarser how treated.*

49. In the larger Works, or where the Gold is mixed with big Sand, Gravel, or Stones, they make use of Wire-Sieves, whose meash is always of one certain size; so as readily to transmit the fine Sand, or Gold Dust, and retain the larger Gravel and Stones behind: For it is extremely rare to meet with any Grain of Gold so large as a Barley-Corn, in the Sands of Rivers. Whence this method by the Sieve is highly serviceable, and conducive to the former Operation: For though a large quantity of fine Sand thus presses the Sieve, it may be readily separated in the Trough, after the Method already described *.

*The End of Stamping and Washing.*

50. And this may suffice to shew the general and particular Methods of Stamping and Washing of Ores. We see the end of these two previous Operations is to get rid of the matters which are not metalline; that so the Furnace may not be uselessly employed upon such Substances as will themselves yield no Metal in the Fire, and only hinder the metallic parts of the Ore from coming together, and affording a Yield answerable to the expence and trouble of the Fusion.

EXPERI-

* § 48.

## EXPERIMENT III.

*Ways of preparing the strongest Fluxes.*

51. We took four Ounces of Red Lead, an Ounce of White Sand, in Powder, and two Ounces of dry decrepitated Salt, and mixed them all well together in a Mortar; then putting the mixture into a clean *Hassian* Crucible, fitted with a Cover, we fused the matter in a Wind-Furnace for a quarter of an hour; when taking it out, and letting it cool, we afterwards broke the Crucible, and found the Salt a-top, and a pure Glass of Lead at the bottom: This Glass we carefully separated and kept apart, as a powerful Flux. *Glass of Lead prepared as a Flux.*

52. The Salt is of no other use in this Operation, than to serve as a Flux to the Sand, and make it more readily unite with the Red Lead; so as to form a Glass without any great violence of Fire, or the necessity of being long detained therein. So that by this means a Glass of Lead may be readily prepared for the purpose of artificial Gems*, or other uses. *Salt, why used therein.*

53. This Glass of Lead is an extremely useful Flux in the business of Assaying; and when kept long in Fusion, passes through the pores of any common Crucible, almost like Water through a Sieve; so as, upon the Test, readily to vitrify, or carry off, all sorts of metalline and mineral matter, except Gold and Silver: On which property, therefore, the Art of Cupelling depends. *The Use of this Glass.*

54. Fluxes seem reducible to two general kinds; *viz.* the *vitreous* and the *saline*. By the *Fluxes of two kinds;*



* See Lect. XIV. Exp. II. and V.

viz. *the vitreous,* *vitreous* we underſtand all thoſe which either have of themſelves, or readily aſſume, a glaſſy form in the Fire; among the principal whereof we reckon the Glaſs of Lead, the Glaſs of Antimony and Borax.

*and ſaline.* 55. By the *ſaline* kind of Fluxes we underſtand all thoſe that are compoſed of Salts, whether Tartar, Nitre, fixed Alkali, or the like. And among the principal of this kind we reckon the Black Flux; which we formerly ſhewed how to prepare *; Sandiver, Kelp, *&c.*

*Their different Uſes.* 56. The vitreous kind ſeem more immediately deſtined to act upon the ſtony or vitreſcible matter, wherewith ſtubborn Ores are frequently mixed; and the ſaline kind, to act more immediately upon the Ore itſelf, for the due excluſion or ſeparation of the Metal.

*Some Ores require no Flux.* 57. The more kindly Ores require no Flux to make them run thin, or to afford all the Metal they contain. And ſometimes Ores are ſo kindly, as to contain their own Fluxes within themſelves. Thus we have met with Copper-Ores, which being barely ground to Powder, and melted, without any addition, in a common Wind Furnace, have yielded as much or even more pure Metal at the firſt Operation than we could obtain from them by means of the uſual Fluxes. Whence we ſee that artificial Fluxes are not always neceſſary; or that the principal uſe of them is for the ſtubborn or leſs tractable Ores. And theſe are ſometimes ſo exceedingly hard to fuſe, and reduce to a metalline form, that it requires the utmoſt power of Art to treat them advantageouſly in the large way of buſineſs, where no conſiderable expence can uſually be allowed for Fluxes. And on this accoun

*Metallurgy improveable by diſcovering cheap Fluxes.*

* See Lect. I. Exp. II.

account it is that many Mines remain unwrought, as being intractable, without great charges. Whence the improvement of the buſineſs of Fluxes, ſo as to render them cheap and effectual, might greatly contribute to the improvement of Metallurgy.

58. We would therefore recommend to farther enquiry what matter it is, in the more ſafe and tractable Ores, which renders them ſo fuſible, and eaſy to part from their Metal. Certain Experiments we have made with this view ſeem to ſhew, that in Copper-Ores it is a kind of bituminous ſubſtance, capable of melting, by a ſtrong heat, into a ſoft and black kind of Glaſs.

*The cheap ſimple Fluxes.*

59. Some of the moſt powerful and cheap ſimple Fluxes hitherto known are dried Wine-Lees, dried Cow-dung and Horſe-dung, dried River-Mud, Fuller's Earth, Iron Filings, common Salt Glaſs, Kelp, or Pot-Aſh, Sandiver, *&c.* which may be uſed in the larger work; as Nitre, Tartar, Borax, Sal-Ammoniac, Mercury-Sublimate, *&c.* may in the ſmaller, or for the making of Aſſays.

*Cheap compound Fluxes.*

60. As for compound Fluxes, they are numerous; almoſt every Operator having his favourite Flux. And certainly ſome Fluxes are better adapted than others to certain Ores. But perhaps a few general ones might be fixed upon, which ſhould ſerve inſtead of all thoſe hitherto commonly known and uſed: We will here recommend three, which are powerful, almoſt general, and not expenſive.

61. (1) Take of Nitre, prepared by long boiling it in Lime-Water; of Sea-Salt, melted in the Fire, Sandiver, and dry Wine-Lees, each one part; Glaſs of Lead, three parts; and powdered Glaſs, eight parts: mix them all well

together. This Flux added, in an equal weight, will fuſe a very ſtubborn Ore.

62. (2) For a ſtill ſtronger, take equal parts of white Tartar, common Salt, and Nitre, prepared as above; calcine them to a white Powder, and mix therewith its own weight of Glaſs and Lead; and of this Flux add two parts to one of the ſtubborneſt Ore.

63. (3) For a powerful ſaline Flux, take of the ſtrongeſt Soapboiler's Lees four Pounds, white Tartar and common Salt, melted in the Fire, each one Pound; boil them together with five Gallons of human Urine, to a dry Salt. This Flux is particularly proper where Sulphur and Cobalt abound, and render the Ore very refractory.

*The Improvement of Fluxes.*

64. But the great Secret in the making and adapting of Fluxes, is not only to ſeparate the Metal already ripened in the Ore, but even to mature and ripen the crude or immature part of the Ore in the Fire, Something of this kind, we apprehend, may be effected; as having reaſon to believe, that certain Fluxes will obtain a larger Yield of Metal from certain Ores, than other Fluxes in common uſe, though eſteemed of the beſt, and though they are perhaps of the deareſt kind. Thus clean Iron Filings will often do more than Borax. But as the Scales and Crocus, or Ruſt, of Iron have been commonly uſed, inſtead of pure and perfect Iron itſelf, for a Flux; few Operators appear acquainted with the excellence of perfect Iron employed for this purpoſe: And many advantages are now commonly reaped by a prudent mixing of one Ore with another of the ſame denomination, and with the Slags or Recrements of Metals, in the way of a Flux.

## AXIOMS and CANONS.

1. We learn from the preceding Enquiry, That to practiſe Minerology and Metallurgy to advantage, a conſiderable knowledge in Natural Philoſophy, and the Operations of Chemiſtry, is required *.

2. That many miſcarriages in mineral attempts have been owing to the want of a competent skill in Mechanics, Hydraulics, and Chemiſtry†.

3. That the profit attending the ſcientifical working of Mines is generally greater, and upon the whole more conſiderable, than that of Agriculture, or Merchandize ‡.

4. That there are two ways of diſcovering Mines; *viz.* by Accident, and by Art: The latter whereof belongs to the intelligent Mineraliſt **.

5. That the Art of diſcovering Mines depends upon a certain ſagacity, which may be acquired by uſe and Practice; or upon the obſervation of particular ſigns, that generally denote a Mine; and again upon the method of Boring, according to ſome analogy of knowledge, gained by being converſant with the common appearances, ſituations, and other Phænomena of Mines ††.

6. That the Art of diſcovering Mines is reducible to Rule; ſo as not to be mere conjecture, or gueſs-work ‡‡.

7. That, in general, Mines are to be firſt opened where a Vein is, by accident, or otherwiſe, laid bare; eſpecially if it prove large or rich: But where no ſuch encouragement appears,



* § 4—6. and Exp. I. II. III. † ib. ‡ § 4—6.
** § 8——13. †† ib. ‡‡ ib.

the ſide of the Hill is principally to be choſe for the opening *.

8. That a deliberate conſideration, and a competency of oeconomical prudence, are uſually required to determine before-hand, whether a Mine, after it is diſcovered, may be wrought to profit †.

9. That the moſt perfect Situation of a Mine is to be mountanous, woody, eaſy of aſcent, healthy, bordering upon a navigable River, and good Roads ‡.

10. That Metals may be ſometimes obtained to advantage without Digging; or barely by waſhing the Sands of certain Springs, and Rivers **.

11. That Mineral Veins differ greatly from each other; and accordingly require different methods of Digging; which may be reduced to ſtandard Rules of Practice ††.

12. That the buſineſs of Mining is improveable by diſcovering better methods of preventing or curing the Damps in Mines, rendering poiſonous Mines wholſome, or defending the Bodies of the Workmen againſt their ill effects; as alſo by diſcovering better methods of raiſing or diſcharging the Waters, following the Veins, breaking the Rock, getting up the Ore, &c. ‡‡

13. That the end of Roaſting of Ores is to diſcharge their ſulphureous, arſenical, antimonial, or other rapacious matters; which would otherwiſe carry off the purer Metal in the melting Furnace, and defraud the account *†.

14 That the richer Ores require neither Roaſting, Stamping, nor Waſhing; but may be directly

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* § 14—16. † § 14——21. ‡ ib. ** § 22, 47—49. †† § 23——26. ‡‡ ib. *† Exp. I.

directly committed to the Smelting-Furnace, without Flux, or Addition *.

15. That in order to roast Ores *per se* in perfection, the Fire should be gentle at first, and afterwards increased up to a degree of Ignition in the Ore †.

16. That some Ores, joined with rapacious mineral Matters, may be advantageously mixed, or stratified, in roasting, with proper fixing Ingredients ‡.

17. That Ores are seldom rendered the poorer, but generally the richer, for Roasting; unless the Fire has been made too strong **.

18. That the business of Roasting of Ores is improveable, and reducible to a few easy Rules, with regard to render the Ore more pulverable, and discharge its volatile, sulphureous, and arsenical parts; which, if retained, would, in strong Fusion, partly prevent the separation of the purer Metal, and partly carry it off into the Air ††.

19. That Metals, in their Ores, are not those fixed Bodies they appear to be in the Bars or Ingots, to which they are reduced by metallurgical operations ‡‡.

20. That the operations of Stamping and Washing are only required in the hard, flinty, and poorer Ores; the design of these operations being merely to separate the useless, terrestrial, or flinty and stony parts; which would otherwise encumber the Furnace, and lessen the Yield *†.

21. That some hard Ores may be softened, or rendered fitter for Stamping and Washing, barely by lying exposed to the open Air; which thus seems to turn some parts of the Ore into a saline

* Exp. I. II. III. † Exp. I. ‡ ib. ** ib. †† ib.
‡‡ Exp. I. II. III. *† Exp. II.

ſaline matter, or Vitriol; whence a kind o friability or ſoftneſs is communicated to th reſt *.

22. That the hardeſt or ſtubborneſt Or may be ſoftened, and rendered fitter for th Stampers, by being firſt ignited, and the quenched in Water; eſpecially if this operatio be ſeveral times repeated †.

23. That the two operations of Stamping an Waſhing are, in good meaſure, reducible t one, in the ordinary Ores; the courſe of th Water being ſo directed under the Stampers, a immediately to carry off the lighter ſtony mat ters, and leave the heavier or more metalli parts behind ‡.

24. That the Sands of certain Rivers may by a ſlight manual operation, be ſometime waſhed for their Gold to conſiderable profit **.

25. That the waſhing of Sand for Gold may be conſiderably expedited, by a proper uſe o the Sieve ††.

26. That Glaſs of Lead is a powerful Flux ſo as to be capable of vitrifying, or carrying away with itſelf upon the teſt, all the metallic or mineral matters that are not either Gold o Silver ‡‡.

27. That the vitreſcible claſs of Fluxes are more adapted to operate upon the ſtony parts of Ores, and the ſaline claſs upon the Ores themſelves, ſo as to ſeparate their Metal *†.

28. That the buſineſs of Aſſaying and the Refining of Gold and Silver, depends upon that property which Lead and the Glaſs thereof have of vitrifying, or carrying off upon the teſt, all the

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* Exp. II. See alſo Lect. III. † Exp. II. ‡ ib.
** § 22. and Exp. II. †† Exp. II. ‡‡ Exp. III. *† ib.

the known matters, except the two nobler Metals *.

29. That ſome Ores naturally contain their own Fluxes; and are therefore beſt aſſayed and ſmelted *per ſe* †.

30. That the buſineſs of Metallurgy might be conſiderably improved, by diſcovering a cheap and general ſet of powerful Fluxes ‡.

31. That an enquiry into the nature of the fuſible matter, naturally contained in the more kindly Ores, might lead to a diſcovery of ſome cheap and powerful Fluxes **.

32. That the large number of compound Fluxes might be reduced to a few general kinds, capable of performing as much as them all ſeverally ††.

33. That the greateſt improvement of Fluxes depends upon making and uſing them ſo as to maturate the Ore, or otherwiſe cauſe a larger Yield than can be procured by the common Fluxes ‡‡.

34. That ſuch maturating Fluxes may be, in ſome degree, obtained by a farther knowledge of the properties, affinities, or relations betwixt Metals and Metals, Metals and Minerals, Ores and Ores, or Minerals and Minerals *†.

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* Exp. III. † ib. ‡ ib. ** ib. †† ib. ‡‡ ib. *† ib.

# LECTURE XVIII.

## CONTAINING

## METALLURGY; *or the Art of* Aſſaying *and working Metals from their Ores.*

*The Subject.*

1. HAVING already conſidered the ſeveral parts of Minerology *, as previous to the Art of *Metallurgy*; we now come to enquire into the Operations of Metallurgy itſelf.

*Metallurgical Operations of two kinds;*

2. Theſe Operations are of two kinds, of ſmaller and larger; with regard whereto the whole of Metallurgy may be divided into two parts; *viz. Aſſaying*, and *Smelting*.

*Aſſaying,*

3. By Aſſaying we underſtand the method of determining by trial, in miniature, what will be the Yield of an Ore in pure Metal when it comes to be wrought in the larger Furnace.

*And Smelting.*

4. And by Smelting we underſtand the ſeveral ways of reducing Ores to pure Metal in the large way of buſineſs, ſo as to fit the produce for the civil, mechanical, and oeconomical uſes.

*Deſign of the Experiments.*

5. We ſhall here enquire into both theſe parts of Metallurgy; or conſider as well the Smelting as the Aſſaying of Ores. Thus the *firſt* Experiment will ſhew the method of Aſſaying and Smelting Gold and Silver; the *ſecond* will ſhew the method of ſeparating Gold from Silver; the *third* will ſhew the method of Aſſaying and Smelting Copper,

* See Lect. XVII.

Copper, Tin, Lead, and Iron; the *fourth* will shew the method of making Brass and Princes Metal; and the *fifth* will exhibit the method of making Steel.

## Experiment I.

### *The Method of Assaying and Smelting Gold and Silver Ores.*

6. (1) We took a Penny-weight of Silver-Ore, reduced to fine Powder; and having put half an Ounce of Lead, cleared of its Silver, into a little flat Essay-Crucible, under a Muffle in the Testing-Furnace, we continued to use a gentle Heat, till the Lead had imbibed the powdered Ore, at least its metallic part, and separated the more stony matter, in form of a glassy *Scoria*, at the top. (2) We now took out the lump of Lead, impregnated with the Silver of the Ore, and placed it upon a *Test*, which had been heating, or nealing, all this while under the same Muffle; and working with a proper degree of Heat, till all the Lead was either evaporated, vitrified, or sunk into the Test, we found a little Bread, or Grain, of Silver left behind; which Grain, or Bread, being exactly weighed, and compared with the original weight of the Ore, gives the proportion of Silver contained in the Ore, or determines its richness: And the same method is equally applicable to Gold-Ores, Sand, or any other matters containing Gold, Silver, or a mixture of both. *Silver Ore assayed by Testing.*

7. This Operation is usually called Testing, or Cupelling; and exhibits almost the whole Art of the Assay-Master and Refiner. We see the Process consists of two parts; *viz. Imbibition*, and *Separation*: For the Lead is first made to *The Operation explained.*

to drink in all the Silver from the Ore; and then the ſame Lead is entirely ſeparated from the Silver. And in this manner alſo are Eſſays taken of Silver Coin, or any mixtures of the nobler with the ignobler Metals: For when the Operation is exactly performed, no other Metals, beſides Gold and Silver, will be left upon the Teſt.

*Its Rationale.*

8. The phyſical reaſon of the preſent Proceſs deſerves to be enquired into. The Laws or Principles whereon it depends are theſe: (1) When the imperfect Metals, or other Minerals, are added to melted Lead, ſome of them will not enter into it, but remain floating on its ſurface in form of a hard *Scoria*; which is the caſe with Iron: (2) Others enter it, but gradually emerge again; as Tin: (3) Others totally exhale; as Regulus of Antimony, and Arſenic: (4) Others again burn to Aſhes, or run into Glaſs, along with the Lead; as does Copper: But (5) neither Silver nor Gold is capable of flying off, burning to Aſhes, or turning to Glaſs, by being detained in melted Lead: Whence theſe two Metals, of courſe, remain pure, and ſeparated from all the reſt, at the end of the Operation. And thus we find, that the Gold and Silver remaining all the time, mixed among the Lead, without going into Glaſs, continually ſink down from the ſhelving ſides of the Teſt, towards the bottom of the Hollow, along with the Lead; which being at length totally conſumed, and the Fire unable to keep Silver or Gold melted without ſome addition of Lead, the Silver and Gold, if any, neceſſarily grow rigid, and fix in a ſmall Grain at the centre of the Teſt.

*Gold and Silver Ores, how treated in the large way;*

9. In the large way of buſineſs, Silver or Gold Ores are treated either by Amalgamation with Mercury; or by ſmelting and refining them with

ith Lead. The method by Amalgamation is ly uſed where the Ore is exceeding rich; par- cularly at the Silver Mines of *Potoſi*: For by inding ſuch rich Ores with Mercury, the bler Metals will be drank up by it, and may readily ſeparated from it again by Diſtilla- n; which carries over the Quickſilver, and aves the nobler Metals behind. Lead is uſed ong with the poorer Ores, in order to drink the nobler Metals they may contain; which does much after the ſame manner by Fuſion, Quickſilver does without; ſo as to ſeparate any heterogeneous parts, by keeping them ating; and afterwards reſtoring the nobler letals, by Cupellation. *By Amalgation,*

10. The large way of ſmelting Gold and Silver res is analogous to the ſmall one of Aſſaying; l things being proportionably larger, the Fire imated with Bellows, and the Blaſt directed on the ſurface of the melted Metal; ſo as to ow off the Lead in the form of Litharge, be- re it is fully vitrified. But here the Silver is t perfectly refined at one operation; ſome roportion of Lead ſtill remaining mixed among , that requires to be burnt out, after the ſame anner, in a ſtronger Fire: And even thus it is ith great difficulty that Silver can be obtained ure, or totally ſeparated, either from Lead or opper. This large way of working might per- aps be improved in reſpect of the Veſſel or Teſt mployed, and the management of the Fire; ſo to work by the means of Flame, without the ſiſtance of Bellows. *And Fuſion.*

11. With regard to the Teſt, we are to ob- rve that Bone-Aſhes, though ever ſo well waſh- and ſifted, are not, perhaps, the fitteſt mat- r to make Teſts of; the Teſts ſo made being t to crack in the Fire, unleſs dried, very gently, *The larger Operation improveable in the Teſt;*

gently, for many days, before they are uſed But there is a particular kind of Talc, or unvi trifiable Sperth-Stone, that being calcined t fine Powder, as it readily may, and made u with a ſmall ſolution of Vitriol in Water, af fords ſuch Teſts as may be immediately uſe without danger of cracking.

*And the Fire.*

12. Again; The Flame of a Wind-Furnac may be made to play upon the ſurface of th melted Metal; ſo as readily to perform thi operation, without blowing with Bellows, tha violently tear away the Silver along with th Lead, in the form of Litharge. And this far ther convenience may be obtained, That no only ſmaller and cheaper Wood, but even Pit Coal, ſhall here ſerve, for the Fewel; provide the ſtructure of the Furnace be contrived for th purpoſe. And in ſome places they have of lat advantageouſly uſed common Pit-Coal for Teſt ing in the large way; and the ſame improve ments might alſo be made in the ſmall way o Aſſaying.

*Aſſaying imperfect.*

13. But how improveable ſoever the buſineſ of Aſſaying may be, it is ſcarce worth the whil to intimate in what particulars it might be im proved; becauſe the Aſſay-Maſters in all coun tries are obliged to make their Aſſays in the man ner peculiar to each country: Whence we ſe one reaſon of the diſagreements ſo frequentl complained of, by Merchants, in the Aſſay made, upon the ſame kinds of Ore, in *Holland Germany*, *England*, *France*, &c. The method employed for this purpoſe all over *Europe* are however, in moſt reſpects the ſame; but ſhoul never be truſted, unleſs, at leaſt, two or thre experiments, made at the ſame time, by th ſame perſon, agree in the ſame report.

14. And

14. And perhaps in all Natural Philosophy, Chemistry, and Metallurgy, there is not an Experiment which requires greater skill, accuracy, and truth of work, than these Experiments, in the Art of Assaying; so as to make them fit to be depended upon: Nor indeed can such Precision as is here required be well expected, but from those who are acquainted with the rapacious nature of many volatile mineral Fumes; and the methods of fixing them, or preventing their carrying off the nobler Metals upon the Test. To assay in perfection also requires a knowledge of the relations and differences of all the Metals with regard to each other; and particularly to Lead and Antimony. As this Art therefore requires so much knowledge, and so much accuracy, in order to practise it with success; hence, doubtless, proceeds the difficulty we find in procuring a true Essay to be made upon any uncommon Ore: For the Art of Assaying is extremely backward in admitting of improvements; as if it were to descend unaltered from one generation to another. *Its Difficulty.*

## Experiment II.

### *The Method of separating Gold from Silver, by Quartation.*

15. We took a mixed Mass of Gold and Silver, and melting it along with three or four times its own weight of pure Silver, we beat the whole lump, when cold, into a thin Plate, which we put into a Glass of Proof *Aqua fortis* *, set in warm Sand; whereby the Silver was soon dissolved, and the Gold let fall in a black Powder *Gold separated from Silver by* Aqua fortis.



* See Lect. VI. Exp. VI.

to the bottom. The Solution of Silver we now carefully poured off, and added a little freſh *Aqua fortis* to the Gold, and uſed a ſomewhat ſtronger Heat than before, in order to diſſolve any remains of Silver in the Gold-Powder. Then the *Aqua fortis* being again decanted, we waſhed the Gold well, in ſeveral parcels of fair Water. And now the Gold-Powder was put into a little Say-Cup, and placed under the Muffle in the Teſting-Furnace, till it became yellow. It might otherwiſe have been melted with Borax; which brings it to its true colour and form. We afterwards weighed the Gold, to determine the proportion it bore to the Silver. Laſtly, we precipitated the Silver out of the *Aqua fortis*, by ſuſpending a Copper-Plate therein; then waſhed the Calx, and reduced it to its metalline form, in the ſame manner.

*Rationale.* 16. The reaſon for adding three or four times the quantity of Silver, in proportion to the mixed Maſs, is, for fear the Maſs ſhould contain too much Gold to be fit for the Operation; or to ſpread the Gold contained in the Maſs, and diffuſe it ſo thinly, that it may not defend the Silver, as it otherwiſe would do, from the action of the *Aqua fortis*. And upon account of this addition it ſeems to be that the Operation is called *Quartation*.

*The Trouble and Expence of the Operation.* 17. This method of ſeparating Gold and Silver was unknown to the Ancients; who therefore ſeparated Silver from Gold by Calcination; and ſo loſt all the Silver that was mixed with the Gold. And indeed the method by *Quartation* is expenſive and laborious; ſo as not to be very advantageouſly practiſed in the large way of buſineſs; though the whole has been divided into ſuch a number of hands, as to make the ſeveral parts come cheap: ſome Operators being wholly

wholly employed in making the *Aqua fortis*; others in purifying it, or bringing it to *Proof*; others in laminating the Silver, and dissolving it; others in separating and reducing the Calx of the Gold; others in precipitating the Silver with Copper; and others again in separating the Copper from the *Aqua fortis*. And hence the whole Operation has been found to answer the trouble, so long as they can recover about a Dram of Gold from a Pound of Silver.

*The Operation improved, or superseded.*

18. But there are certain Workmen of late, who have the method of separating Gold from Silver to much greater profit, without the use of *Aqua fortis*, or *Aqua regia*, and barely by a dexterous application or management of the Fire; at least without any costly additions. This method is kept as a Secret; but may, perhaps, be no other than that published by M. *Homberg**; which consists in fluxing the mixed Mass of Gold and Silver with equal parts of rough Nitre and decrepitated Salt, placed at the bottom of the Melting-Pot; whereby the Operation, in the large way, may be finished in a quarter of an hour; the Gold thus falling to the bottom, and leaving the Silver suspended or detained in the Salts. Another way of effecting this separation may depend upon a dexterous use of Sulphur; which has the power of making Silver melt away from a metalline mixture almost as easy as Lead †.

*Gold, how to be obtained pure.*

19. But to obtain either Gold or Silver in absolute purity, is no easy task. For the common uses, indeed, the methods above delivered may serve; but for the more curious chemical and philosophical purposes, better ways than



* In the *French* Memoirs.

† See below § 20.

are commonly known and practiſed ſhould be diſcovered. To refine Gold by melting and teſting it with Antimony, or Glaſs of Antimony, is generally, and even by the metallurgical Chemiſts, thought a perfect way; but M. *Homberg* * has ſhewn, that even this Criterion, as alſo Quartation, Cupelling with Lead, Fluxing with Borax, *&c.* may fail, in caſe the Gold be mixed with *Emery*, or poſſibly ſome other things. When Gold is *eager*, as the Workmen call it, that is, brittle, they hold it as a Secret to melt it with Mercury-Sublimate. But perhaps no Gold can be proved to be perfectly pure, till it has gone through all the trials hitherto known; or even ſome of a more curious nature; particularly melting with crude Antimony, and afterwards cupelling the Regulus with Lead; and, at laſt, fuſing it with Borax. Which Proceſs we recommend to thoſe who require Gold in abſolute purity for any Standard, or very curious Operation.

*Silver, how.* 20. The methods of obtaining Silver in purity are various, and differ according to the Metal wherewith the Silver is mixed, or allayed. If Copper be the Allay, the beſt and cheapeſt way to purify the Silver is, to calcine it with half its weight of common Sulphur; then melt the whole together; and throw into the Pot, at ſeveral times, a due quantity of clean and new Filings of Iron; which will immediately make the Sulphur quit the Silver, and form a Scoria a-top; leaving the Silver free from Copper, Iron, or Sulphur, at the bottom.

EXPERI-

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* See the *French* Memoirs.

## Experiment III.

*The general Method of Assaying and Smelting the impurer Metals; Copper, Tin, Lead, and Iron.*

21. We took four Ounces of Lead-Ore, reduced to Powder, and mixing it with an Ounce of the clean Filings of pure Iron, and half an Ounce of the Black-Flux *, we melted them all together, in a new Crucible, set in a Wind-Furnace; and by this means found the Lead clearly separated, in a lump, at the bottom of the Crucible; after it was taken out of the Fire, and suffered to cool. *Lead-Ore assayed.*

22. The method of thus working in Crucibles, and by the help of Fluxes, is not only too small, but also too chargeable, to answer in the large way of business: Nor is there any occasion for being confined to this method; since Fusion in a naked Fire, or in contact with the burning Fewel, is found to act as a powerful Flux, and get the Metal out of Ores to advantage. Hence we every where find that Metals are smelted in open Furnaces, with a naked Fire. And though this has long been a general practice, the physical reason of it seems little known; insomuch that nothing is found more wanting in philosophical Metallurgy, than the particular *History of common Fusion.* *How smelted in the open Fire.*

23. The Ores of Lead, Tin, Copper, and Iron, are all commonly fused in contact with the Fewel of the Furnace; the prepared Ore being at first stratified, or intermixed with the Wood or Coals: Nor could these Ores any other way be fused, in a large quantity, so as *The Rationale.*



* See Lect. I. Exp. II.

to acquire a metalline form, though urged with ever ſo ſtrong a Flame, or beat ever ſo violently upon by the Fire, whilſt they were kept from touching the Coals, by being included in a large Crucible, or Melting-Pot, after the manner that Glaſs is made; or whilſt no Flux-Powder, of an oily or inflammable nature, was added *. Even if the Ore thus treated were rich, or naturally contained ſome viſible Grains of pure Metal; this Metal would only remain almoſt in the ſame ſtate as it was, without enlarging its bulk from the reſt of the Ore: Whereas if a little powdered Charcoal be thrown in, or the Ores were committed to a naked Wood-Fire, they preſently reſolve into Metal.

*The metallic nature how preſerved, or recovered.*

24. We might obſerve in our Experiment of Cupellation †, how extremely apt theſe imperfect Metals are to receive a deſtructive alteration in the Fire, or to be burnt and reduced to Aſhes, or Glaſs, along with the Lead; on which diſpoſition of them the Art of Cupelling depends. But by contriving to melt theſe Metals in contact with the Coals, their metallic form is greatly preſerved; eſpecially as the ſtony, vitrifiable matter, wherewith ſuch Ores are uſually mixed, occaſions them, by their clinging nature, to unite more intimately with the glowing Coals.

*Metalline Calces reduced.*

25. This Doctrine receives a remarkable confirmation from the uſual Method of recovering Metals burnt to Aſhes at the Smelting-Furnace: For if the Litharge, blown off in teſting, or even the Glaſs of Lead, or the Aſhes of any other of the imperfect Metals, be barely melted, in contact with Charcoal, they thus preſently recover their metalline form. And the ſame thing

is

* See Lect. II. *paſſim*. † See Exp. I.

is likewise affected by the addition of any unctuous or inflammable matter; whence it seems to be the unctuous or inflammable matter of the Coals which thus insinuating into the metalline Calces, restores their metallic nature. And we have several times, in the course of these Lectures, had occasion to observe the great affinity there is betwixt Oils and Metals*; insomuch that their true metallic form, or softness, and ductility, seem entirely owing thereto.

26. There are three things, therefore, to be principally regarded in the Smelting of Ores; *viz.* (1) the Fusibility of the Metal; (2) the Fusibility of the Scoria; and (3) the Contact or Mixture of the metallic matter with the inflammable part of the Coals. *Three things to be regarded in Fusion;*

27. (1) Different Metals run in different manners from their Ores. Thus Lead, though extremely fusible in the Metal, yet runs with difficulty from the Ore; so as to require a considerable violence of Fire. This stubbornness, not belonging to the Metal, must be attributed to the stony, sulphureous, or other mineral matter, wherewith the Ore is mixed; which matter seems to require a degree of heat capable of vitrifying the Lead, before the Metal will run: But then the Lead thus vitrified recovers a metallic form again, by coming in contact with the Coals. *viz. The Fusibility of the Metal: Instanced in Lead.*

28. In the case of our present Experiment, the Iron-Filings laying hold of the sulphureous parts of the Ore, leave the Lead at liberty to run much sooner, and freer, from the Stone: Where also the great degree of heat communicated by the Iron-Filings, and their inflammable



* See Lect. VI. Exp. II. *& alibi passim.*

nature, must have a considerable effect, at the same time that they will not incorporate with Lead, but, in Fusion, float on its surface.

*Tin, Copper, and Iron.* 29. Tin runs from its Ore with greater ease than Lead; and is therefore smelted in much less Furnaces: But Copper requires an intense Heat, or a Blast-Furnace; and Iron, the greatest Heat that can be given in a Furnace: and both Iron and Copper absolutely require immediate contact with the Fewel employed. Hence it appears, that each Metal must have its determinate degree of Heat, to run it with advantage from the Ore or Stone.

*The Fusibility of the Slag.* 30. (2) In order, likewise, to obtain the Metal from the Ore to best advantage, the Scoria, or Slag, must be necessarily made to run thin and fluid; otherwise it entangles or invisicates the Metal, and will not let it separate fully. And hence we frequently observe, in the Assaying of Copper Ores, small grains of Metal interspersed, here and there, among the *Scoria*, that require to be separated by stamping and washing the whole Mass; which labour might have been prevented, by using a proper degree of Heat, capable of procuring a thin Fusion, and a suitable Flux; so as to have made all the Metal fall to the bottom of the Crucible; which it constantly does when the Operation is well performed.

31. To promote a thin Fusion of the Slag, in the larger Furnace, it is often proper to use the more soft and fusible Sands as a Flux; and sometimes that Loamy-Sand, which the Smiths employ for the welding of Iron; this Sand readily vitrifying, and adhering to the Metal in the Fire: And where it will answer the charge, even Litharge, or Dross of Lead, might be used for this purpose, in the larger Furnaces; for scarce

any

any thing procures ſo thin a Fuſion of the Slag, as Lead.

32. In the large work, Sulphur is found to adhere tenaciouſly to Copper; which Metal, therefore, ſeldom comes out pure in the Furnace, without repeated Fuſions. The beſt method of ſeparating this Sulphur, is, to uſe a violent Heat, no additional Flux at all, and the greateſt draught of Air that can any way be procured; ſo that all things may conſpire to burn out, or carry off, the Sulphur, and introduce, in its ſtead, a thing of a different nature; *viz.* the inflammable matter of the Coals; whereon, as we before obſerved, ductility appears to depend. But where Iron is mixed with Copper, no better addition is found than Sulphur, and the more ſulphureous Marcaſites; or what they at the Smelting-Huts call *Marcaſite Blocks:* For the Sulphur which theſe contain cauſes the Copper readily to run away from the Iron, and leave it behind in the Furnace. And here the power which Sulphur has upon the ſeveral Metals is very remarkable. We before obſerved, that it renders Silver almoſt as fuſible as Lead *: It alſo greatly increaſes the Fuſibility of Iron, and Regulus of Antimony; but renders Tin much leſs fuſible than it is of itſelf; and Lead, even refractory in the Fire: Whence certain Rules might be formed, for the uſe and application of Sulphur to Metals, for the improvement of Metallurgy. And thus the whole Art of Smelting ſeems to depend upon knowing the degree of Heat required by every Ore; ſo as to make the Slag, as well as the Metal, run thin, and evaporate, or diſcharge the ſulphureous parts; and, laſtly, introduce the proper metallic,

*Sulphur how ſeparated from Copper.*

* Exp. II. § 18.

tallic, ductile form, by means of an unctuous or inflammable matter.

*Consequences of inartificial Fusions and Separations.*

33. It seems principally owing to a defect in the knowledge of Fusion, that so many Recrements, or Slags, of Metals, anciently thrown, as useless, from the Furnace, have been wrought to considerable profit of late, by more skilful Workmen; at least it seems more rational to attribute the success to this course, than to any supposed growth of Metals in such Slags: So likewise it is currently believed, that Lead has grown rich in Silver, by lying exposed to the open Air, or by long covering Churches, or other Buildings; whilst perhaps it is rather owing to the unskilfulness of the former Workmen, who were not able to separate all the Silver naturally contained in Lead. And thus it appears certain, that the ancient Metallurgists were unacquainted with any way of extracting, to profit, a small quantity of Silver out of Copper; which is now commonly done by an ingenious contrivance*: Whence the ancient Copper found upon Temples, or other Buildings, frequently contain Silver. So likewise in the *Forest of Dean* they at this day work the Slag of their old Iron-Works over again to profit.

*Metals to be carefully cooled.*

34. All moisture, and too sudden cooling, prove prejudicial to the more ignoble Metals after Fusion; and sometimes dangerous to the Operator. A little Water falling upon melted Iron or Copper makes them expand with prodigious violence, and discharge themselves abroad with a force like that of a Canon: And even sudden cooling will often occasion the surface of the Metal to crack, and suffer the more internal part, not yet set or fixed, to issue out to a con-

* See below § 35.

a conſiderable diſtance; whence either loſs of the Metal or miſchief may enſue. But to prevent theſe ill effects, after Cupellation, it is uſual for the Operator to throw a quantity of Water, all at once, upon the lump of Silver, as it lies in the Teſt, at the moment that it begins to grow rigid; for thus the Water, by its coldneſs, ſuddenly makes ſo thick a cover upon the ſurface of the Silver, that the hotter parts on the inſide cannot break through the upper: Whence that ſpringing, or ſpouting out, of the Silver, which we ſometimes ſee in the ſmaller way of aſſaying upon the Teſt, when the Metal ſpontaneouſly cools, is entirely prevented.

*The ignobler Metals how ſeparated from each other;*

35. We have already conſidered how Gold and Silver are to be ſeparated when mixed *; we ſhould alſo know how the leſs noble Metals may be ſeparated from one another: This is done either by means of Fire alone, or by means of Lead. Thus Copper, being more fuſible than Iron, will, in a proper Furnace, melt, and run entirely from it; whilſt the Iron is not made to flow with the ſame degree of heat as melts the Copper, or elſe ſticks behind in the Slag. After the ſame manner Lead, being more fuſible than Copper, readily runs away from it, in a Furnace kept of a due heat for the purpoſe. A mixture of Iron and Lead is ſeparated in the ſame manner; the Iron floating upon the ſurface of the Lead. Copper, Tin, Iron, Antimony, *&c.* we before obſerved might be ſeparated from Gold or Silver, by teſting with Lead †; but then the ignobler Metals are loſt. And where only a ſmall proportion of Silver is mixed with a large one of Copper, this method would prove uſeleſs, or prejudicial: Nor

*viz. Iron from Copper.*

*Lead from Copper.*

*Iron from Lead.*

* See Exp. II. † Exp. I.

*Silver from Copper.* Nor can a ſmall proportion of Silver be well ſeparated from Copper, by any method hitherto known; ſo as to preſerve the Copper pure, or eaſily recoverable: Whence at the Smelting-Huts the method is, to get the Silver out of *imperfect Copper*, or whilſt it ſtill remains mixed with its own Sulphur, under the form of what they call *Black Copper*; which they melt, and ſuffer to run among a large proportion of melted Lead; then caſting the mixture out into large Blocks, theſe are carried to a particular Furnace, and there ſet upright, ſo as that the Fire, being lighted a-top, may commodiouſly play between them. And thus the Lead melts away from the Blocks, carrying with it the Silver before contained in the Copper; the Blocks of which Metal are now left hollow, porous, ſpungy, and wrinkled. Theſe exhauſted Blocks are then removed to a hotter Furnace, in order to be farther drained of their Lead. The laſt remains are, now in another Furnace, reduced to perfect Copper; and the whole parcel of Lead, thus enriched, committed to the Teſt, in order to ſeparate the Silver.

*Copper Ore teſted.* 36. In the ſame manner may Copper Ores be aſſayed, by teſting them with a ſmaller proportion of Lead than is uſed to Silver Ores; tho' this Operation requires a great degree of care and exactneſs, to prevent the Copper from being carried off with the Lead, or vitrified. So likewiſe when Copper happens to be mixed with Iron, the beſt method of ſeparating them, in the way of Eſſay, is to melt them with Lead; which readily imbibes the Copper, but throws the Iron to the ſurface; where being entangled with the vitrified *Scoria* of the Lead, it may be taken off, and the Copper thus brought to a great degree of purity; though indeed it is apt

to

to loſe a little of its ductility, on account of ſome very minute proportion of Lead, or its Fumes, remaining therein.

37. We have not here confined ourſelves to the conſideration of one Metal more than another; but endeavoured, under the preſent Experiment, to ſhew the ways of treating all the ignobler kinds, or working them, in the beſt manner, from their Ores. It is eaſy to apply this general Doctrine, occaſionally, to the treatment either of Lead, Tin, Copper, or Iron. *The Doctrine general.*

## Experiment IV.

### *The Method of making Princes Metal.*

38. We took ſix Ounces of Copper, and melting it in a Wind-Furnace, added to it an Ounce of Zink; then ſtirring the whole well together, we immedlately poured out the Metal. The Copper and the Zink may be put into the Crucible together, if firſt covered over with the Black Flux; which prevents the avolation of the Zink, or preſerves its metalline form. *A mixed Metal of Copper and Zink.*

39. This is an expeditious method of making a fine kind of Braſs; whereas the common method with *Lapis Calaminaris* requires a conſiderable length of time, and a violent Fire: For this purpoſe they calcine and powder the Calamy; then mix it with a little Charcoal-duſt; and to ſeven Pounds of this mixture add five of Copper-Plates; then giving eleven or twelve hours Fire, the Copper imbibes about one third of its weight of the Calamy. *Braſs how made.*

40. It is here remarkable that the Calamy, though no compleat metallic Body, nor malleable, ſhould yet concrete along with the Copper, ſo as not only to increaſe its weight, but alſo to extend *The nature of Calamy.*

extend with it under the Hammer; which Zink, in making the Princes Metal, does not do, though it appear in all reſpects of a more metallic nature than Calamy.

*And Zink.* 41. The agreements and diſagreements of theſe two Bodies, Zink and *Lapis Calaminaris*, may deſerve to be farther enquired into, by particular Experiments. The Inflammability of Zink is very remarkable; for it burns durably of a bluiſh white Flame in the Fire; and thus reſolves into a white Calx.

*Imitations of Gold.* 42. Many curious Phænomena, and unexpected reſults, happen upon mixing metallic and mineral Bodies in the Fire; all which deſerve to be tried, and noted, as facts that might at leaſt direct the diſcovery of ſeveral new and uſeful mixtures, or compoſitions of Metals. We might be encouraged to proſecute this Enquiry, from thoſe pretty imitations of Gold, lately introduced, for the making of Watches, Buckles, Cane-heads, Snuff-boxes, *&c.* But perhaps a better imitation of Gold, for theſe and many other purpoſes, may be obtained by M. *Homberg*'s method of treating Copper with Quickſilver: For if an Amalgam be made of one part pure Copper, and three parts Quickſilver; and the Amalgam be boiled in River-Water, for two hours; then have the Quickſilver diſtilled off, and cohobated once; the remaining Copper, being now fuſed, will be found of a beautiful Gold Colour, and more ductile than common Copper; ſo as to become well fitted for Watch-work, Gilding, and the finer Machines and Utenſils.

*Homberg's Metal.*

EXPERI-

## Experiment V.

*The Method of converting Iron into Steel.*

43. We took a few pieces of soft Iron-Wire, and burying them in a close Crucible, full of powdered Charcoal, set the whole in a Wind-Furnace, for two or three hours; then taking out the pieces of Wire, found them changed to Steel. *Steel made.*

44. The method of making Steel has been usually kept as a Secret; and at present there are but very few Steel-makers in *England*. The ancient method was, to keep slender Bars of Iron ignited, for several hours, in a melted mixture of Iron and vitrescible Sand; then taking out the Bars, and forging them, and immediately plunging them, whilst hot, into cold Water; afterwards forging them again, till they would easily snap, and appear white, and of a close Texture, or Steel-Grain, when broke. *The ancient Method.*

45. The present method is, to stratify a large number of slender Iron Bars, with powdered Charcoal; and fill a Furnace with them, in the form of a long Chest; then keeping up a strong Fire, but so as not to melt the Iron, for two or three days together. And thus the Bars are at length, when the Furnace is cold, taken out unaltered in their external form: But they may be blistered according to the pleasure of the operator, by using Quicklime along with the powdered Charcoal. *The modern Method.*

46. The whole Secret of making Steel seems to depend upon excluding the Air from the Iron to be wrought upon. Accordingly if a large Ball of Iron be kept so hot, for some time, that its external surface shall melt, and run like Water; *Whereon the Operation depends.*

Water; the internal part of the Ball will, at the ſame time, be converted into true Steel. And hence appears the reaſon why certain Knots, or Spindles, of Iron are ſometimes found in the middle of Caſt-Work, ſo hard that no Tool will touch them.

*Caſe-hardening.*

47. The Art of Caſe-hardening is a leſſer degree of Steel-making; and practiſed by baking Raſors, Files, Knife-Blades, *&c.* in a kind of Oven, ſtratified with powdered Charcoal, Hoofs, Horns, and the like, ſo as to exclude the Air; and thus, by baking, to give a Coat of Steel to Inſtruments, ſome depth below their ſurface.

*The beſt Steel, how made.*

48. But the making of the beſt Steel depends upon the nature of the Iron employed, or its Ore; and uſually requires a proper mixture of ſeveral kinds together, as well as perfection in the Art of Tempering; which, according as it is managed, ſuits the Steel for different uſes. Thus Gravers are of one temper, Drills of another, Watch-Springs of another, Razors of another, *&c.* Which tempers are given them by being quenched with different heats in Tallow, Water, or certain Liquors, Juices, or the like.

## AXIOMS and CANONS.

1. We learn from the foregoing Enquiry, That different mineral and metallic matters bear different relations to melted Lead in Fuſion. Whence ſome of them will not mix therewith, but float on its ſurface: That others evaporate, and others vitrify it; whilſt Silver and Gold remain unaltered by it, and unimpaired *.

2. That the nobler Metals have nearly the ſame relation to Quickſilver, as they have to melted

* Exp. I.

melted Lead; as being readily drank up by them both, ſo as thus to be ſeparated from other heterogeneous matters *.

3. That Teſting, in the large way, is improveable by finding a properer matter than Bone-Aſhes, for the making of Teſts, by working without Bellows; and again by uſing Pit-Coal, and a well contrived Furnace †.

4. That the Art of Aſſaying is hitherto imperfect; but capable of receiving conſiderable improvement from chemical and mechanical knowledge ‡.

5. That the troubleſome and expenſive method of ſeparating Gold from Silver by *Quartation*, may be advantageouſly ſuperſeded, or ſet aſide, by means of Fuſion, or a dexterous management of the Fire **.

6. That Gold and Silver are rarely rendered abſolutely pure, or ſeparated from all other kinds of metallic or mineral matters; and that to purify them in this manner, requires the uſe of better methods than thoſe commonly uſed for the purpoſe; though the thing is ſtill performable by Art, and a ſuitable Proceſs ††.

7. That the particular *Hiſtory of common metallic Fuſion* is wanting, for the improvement of Metallurgy ‡‡.

8. That when the Ore of an imperfect Metal is in immediate contact with the Fire or Fewel, it yields the more and the better Metal, than when contained in a Crucible, or kept from touching the Coals *†.

9. That a languid Fire leſſens the Yield of an Ore; but a brisk one, if not too long continued, increaſes it †*.



* Exp. I. † ib. ‡ ib. ** Exp. II. †† ib.
‡‡ Exp. III. *† ib. †* ib. See alſo Lect. XVII.

10. That the buſineſs of Smelting in perfection depends, (1) upon uſing a degree of Fire ſuited to the Ore; (2) procuring a quick and thin Fuſion of the Scoria; and (3) a cloſe contact of the Metal with the Fewel, or Coals, employed *.

11. That Sulphur has different effects upon the different Metals; which effects being well noted, Rules of Practice might be thence derived, for the farther improvement of Metallurgy †.

12. That metalline Recrements, or the Slags of Metals once ſmelted, have been wrought over again to profit, on account of the imperfect manner wherein the Ores were originally treated for their Metals ‡.

13. That the ignobler Metals are ſeparable from each other by the application of proper degrees of Heat; ſo as to make the more fuſible melt away from the leſs fuſible; at leaſt with the aſſiſtance of Lead **.

14. That all Metals are reducible, by burning, or Calcination, to terreſtrial Powders, or *Calces*; which, by being melted with any inflammable matter, aſſume their metalline form again ††.

15. That the great enemies to ductility, or the true metallic nature, are Sulphur, Cobalt, and things compounded thereof ‡‡; but that all unctuous or inflammable Bodies are friendly to Metals, and promote or reſtore their ductility, when melted therewith *†.

16. That Copper may be made to approach the colour of Gold, and at the ſame time not loſe, but increaſe, its ductility, by being amalgamated with, and diſtilled from, Quickſilver; and

* Exp. III. † ib. ‡ ib. ** ib. †† ib. ‡‡ Exp. III. See alſo Lect. XVII. *† Exp. III.

and that probably many artificial or compound Metals are diſcoverable, by mixing various metalline and mineral Bodies together; ſo as greatly to enrich and improve the Art of Metallurgy *.

17. That Steel is made by a proper application of Fire to Iron, in a cloſe place, ſo as to prevent the open Air from communicating freely with the Iron †.

18. That Metals receive particular alterations in their Texture, or Conſiſtence, according to the nature of the ſolid Subſtance, or Liquor, wherein they are quenched, or cooled ‡.

19. That, in general, Ores are no more than a natural, looſe mixture of metallic matters, along with earthy and ſulphureous ones: Whence artificial Ores may be readily made, by calcining a Metal with Sulphur, and mixing it with Earth; ſo as, with Heat, to form ſolid lumps of Ore, reſembling thoſe dug out of Mines **.

20. That numerous Experiments remain to be made, and facts of nature, or obſervations, to be regiſtered, or the relations of Bodies to be found, before this uſeful Subject of Metallurgy can be brought to perfection ††.

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* Exp. IV. † Exp. V. ‡ ib. ** See Lect. XVII. and XVIII. *paſſim*. †† Exp. I. II. III. IV. V.

# LECTURE XIX.

## CONTAINING

PYROTECHNY; *or Experiments relating to* Gunpowder, Explosions, *and* Phosphori.

*The Design.* 1. THE present Design is to enquire into the nature of Gunpowder, Explosions and *Phosphori*; to try if any useful doctrine, or discoveries, may be thence derived for the improvement of Chemistry and Natural Philosophy. We propose, (1) to examine into the nature and composition of Gunpowder with the ways of trying and improving it; (2) to shew some of the more remarkable kinds of Explosions; (3) to examine some of the more eminent *Phosphori*; and (4) to deliver the Doctrine pointed out by this kind of Experiments.

*The Intent of the Experiment.* 2. Our *first* Experiment, therefore, will shew the method of making Gunpowder; our *second* the method of making the *Pulvis* and *Aurum fulminans*; our *third*, a method of producing Heat and Fire by the mixture of Sulphur and Iron Filings; our *fourth*, a method of producing Coruscations, with Oil of Vitriol and Iron Filings; our *fifth*, a method of producing Fire and Flame by the mixture of two cold Liquors; and our *sixth* Experiment will shew the method of making the liquid Phosphorus of Urine.

EXPERI

## Experiment I.

### *The Method of making Gunpowder.*

1. We took four Ounces of refined Salt-Petre, an Ounce of Brimſtone, and ſix Drams of Small-Coal; theſe we reduced to fine Powder, and continued beating them, for ſome time, in a Stone-Mortar, with a Wooden Peſtle; wetting the mixture, between whiles, with Water, ſo as to form the whole into an uniform Paſte; which was reduced to Grains, by paſſing it through a Wire-Sieve fit for the purpoſe: And in this form, being carefully dried, it becomes the common Gunpowder. *Gunpowder made.*

2. We formerly ſhewed the way of refining Salt-Petre for the making of Gunpowder *. In order to reduce this Salt to Powder, they diſſolve a large quantity of it in as ſmall a proportion of Water as poſſible; then keeping it continually ſtirring over the Fire, till the Water exhales, a white dry Powder is left behind. *Nitre how pulverized readily.*

3. In order to purify the Brimſtone employed, they diſſolve it, with a very gentle Heat; then ſcum and paſs it through a double Strainer. If the Brimſtone ſhould happen to take fire in the melting, they have an Iron-Cover that fits on cloſe to the melting Veſſel, and damps the Flame. The Brimſtone is judged to be ſufficiently refined, if it melts without yielding any fetid Odour, between two hot Iron Plates, into a kind of red Subſtance. *The Sulphur purified.*

4. The Coal for the making of Gunpowder, is either that of Willow, or Hazel, well charred in the uſual manner, and reduced to Powder: And thus the Ingredients are prepared for making *The Coal prepared.*



* See Lect. XIII. of *Salts*.

*The Stamping.* king this Commodity. But as these Ingredients require to be intimately mixed; and as there would be danger of their firing if beat in a dry form; the method is to keep them continually moist, either with Water, Urine, or a Solution of Sal-Ammoniac; and to continue thus stamping them together for 24 hours; after which the Mass is fit for corning, and drying in the Sun, or otherwise, so as sedulously to prevent its firing.

*Rationale of Gunpowder.* 5. The explosive force of Gunpowder is now a thing commonly known; but the physical reason thereof may not, perhaps, be hitherto sufficiently understood. In order to explain it, let us observe, (1) that Salt-Petre, of itself, is not inflammable; and though it melts in the Fire, and grows red hot; yet does not explode, unless it comes in immediate contact with the Coals; (2) that Brimstone easily melts at the Fire, and easily catches Flame; (3) that powdered Charcoal readily takes fire, even from the Sparks yielded by a Flint and Steel; (4) that if Nitre be mixed with powdered Charcoal, and brought in contact with the Fire, it burns and flames; (5) that if Sulphur be mixed with powdered Charcoal, and applied to the Fire, part of the Sulphur burns slowly away, but not much of the Charcoal; and (6) that if a lighted Coal be applied to a mixture of Nitre and Sulphur, the Sulphur presently takes fire, with some degree of Explosion, leaving a part of the Nitre behind; as we see in making the *Sal Prunellæ* and *Sal Polychrestum.*

6. These Experiments duly considered, may give us the chemical cause of the strange explosive force of Gunpowder: For each Grain of this Powder consisting of a certain proportion of Sulphur, Nitre, and Coal, the Coal presently

ly takes fire, upon contact of the ſmalleſt Spark; at which time both the Sulphur and the Nitre immediately melt, and, by means of the Coal interpoſed between them, burſt into Flame; which, ſpreading from Grain to Grain, propagates the ſame effect almoſt inſtantaneouſly; whence the whole Maſs of Powder comes to be fired: And as Nitre contains a large proportion both of Air and Water, which are now violently rarified by the Heat, a kind of fiery exploſive Blaſt is thus produced; wherein the Nitre ſeems, by its aqueous and aerial parts, to act as Bellows to the other inflammable Bodies, Sulphur and Coal, blow them into a Flame, and carry off their whole ſubſtance in Smoak and Vapour.

*Its Diſcovery.*

7. The diſcovery of this Compoſition was accidental, and perhaps owing to that common operation of fulminating Nitre with Sulphur, for the making of *Sal Prunellæ*: It appears to have been known long before the time of *Swark*, as being particularly mentioned by Frier *Bacon*.

*The Ingredients differently proportioned.*

8. The three Ingredients of Gunpowder are mixed in various proportions, according as the Powder is intended for Muſquets, Great Guns, or Mortars: Though theſe proportions ſeem not to be hitherto perfectly adjuſted, or ſettled by competent experience.

*How tried as to purity.*

9. There are two general methods of examining Gunpowder; one with regard to its purity, the other with regard to its ſtrength: Its purity is known, by laying two or three little heaps near each other upon white Paper, and firing one of them; for if this takes fire readily, and the Smoke riſes upright, without leaving any droſs, or feculent matter, behind, and without burning the Paper, or firing the other Heaps, it is eſteemed a ſign that the Sulphur and Nitre were

were well purified; that the Coal was good; and all the three Ingredients were thoroughly incorporated together: But if the other Heaps alſo take fire at the ſame time, 'tis preſumed that either common Salt was mixed with the Nitre, or that the Coal was not well ground, or the whole Maſs not well beat and mixed together; and if the Nitre or Sulphur was not well purified, the Paper will be black or ſpotted.

*How as to Strength.* 10. In order to try the ſtrength of Gunpowder, there are two kinds of Inſtruments in uſe; but neither of them appear more exact than the common method of trying to what diſtance a certain weight of Powder will throw a Ball from a Muſquet.

*How ſtrengthened.* 11. To increaſe the ſtrength of Powder, it ſeems proper to make the Grains conſiderably large, and to have it well ſifted from the ſmall Duſt. We ſee that Gunpowder reduced to Duſt has little exploſive force; but when the Grains are large, the Flame of one Grain has a ready paſſage to another; ſo that the whole parcel may thus take fire nearly at the ſame time; otherwiſe much force may be loſt, or many of the Grains go away, as ſhot, unfired.

12. It ſhould alſo ſeem, that there are other ways of increaſing the ſtrength of Powder; particularly by the mixture of Salt of Tartar: But perhaps it were improper to divulge any thing of this kind, as Gunpowder ſeems already ſufficiently deſtructive.

*White Powder.* 13. There has been much talk of a *white Powder*; which, if it anſwered the character given it, might be a dangerous thing: For they pretend, that this white Powder will throw a Ball as far as the Black; yet without making a Report. But none of the white Powder which we have

have ſeen anſwers to this character; being, as we apprehend, commonly made either with Touch-wood or Camphire, inſtead of Coal. The moſt dangerous white Powder, if it may be ſo called, is condenſed Air; which, though able to diſcharge a Ball, with great force, to a conſiderable diſtance, makes no loud Report; eſpecially when not violently condenſed, as it need not be to have pernicious effects.

14. And how far Wind-Guns are improveable, has not, perhaps, been well conſidered: Some of them we have ſeen diſcharge a great number of Bullets ſucceſſively; even the laſt whereof would go through an Inch-Plank, at the diſtance of ſeveral yards: So that this Machine might anſwer the ſame end as a Muſquet. But whether it be practicable to make great Guns in the ſame manner, is another conſideration; and chiefly depends upon finding a Spring ſufficiently ſtrong to reſiſt the violent force wherewith Air might be condenſed by the uſe of a Winch, *&c.* *Wind-Guns.*

## Experiment II.

### *The* Pulvis *and* Aurum fulminans *prepared.*

15. We took three Ounces of purified Nitre, two Ounces of Salt of Tartar, and one Ounce of Brimſtone, and ground them well together in a Mortar; then putting a ſmall quantity, as about half a Dram, of this Powder upon an Iron Plate, and placing it over a gentle Fire, as ſoon as the Powder juſt began to melt, it made a ſmart and loud Exploſion. *Pulvis fulminans prepared.*

16. The more philoſophical way of accounting for this effect of the *Pulvis fulminans*, is by ſuppoſing that the acid Spirits of the Nitre and Sulphur *Its Effect accounted for.*

Sulphur, being looſened by the Heat, ruſh towards one another, and towards the Salt of Tartar, with ſo great a violence, as, by the ſhock, at once to turn the whole into Vapour and Flame.

*Aurum fulminans prepared.*

17. We diſſolved a few Grains of fine Gold in *Aqua regia*; then precipitated the Solution with Salt of Tartar; and thus obtained a Powder, which we dried with a very gentle Heat. A ſingle Grain of this Powder being laid upon the point of a Knife, and held over a lighted Candle, preſently went off, with a very brisk and loud Report.

*Its odd Properties.*

18. This *Aurum fulminans* has other remarkable properties; for (1) it does not, like the *Pulvis fulminans*, and Gunpowder, require the application of actual Fire to make it explode; but though prepared with two of the moſt fixed Bodies, Gold, and Salt of Tartar, yet is ſo volatile as to fly off, and give this loud Report, with a leſs degree of Heat than ſuffices to kindle any of the moſt inflammable Bodies; or even by being ſtrongly rubbed in a Mortar, or dried on a hot Furnace: (2) It exerts its exploſive Force *in vacuo*, as well as in the open Air; and when made to explode in the exhauſted Receiver, a fine Gold Duſt has been found ſticking to the ſides of the Glaſs. (3) The addition of a little Brimſtone to this Powder takes away its fulminating property; ſo that after having been melted therewith, the Gold is ſet looſe, and may be eaſily recovered, in its native form, by fluxing it with Borax.

*The Rationale.*

19. Hence it ſhould ſeem that the Body of the Gold in this Powder is ſubtilly divided by the action and interpoſition of the parts of the compound Menſtruum; which Menſtruum being of an

an aqueous and aerial nature, and its parts closely wedged in betwixt the fine ponderous parts of the Gold in the *Aurum fulminans*, when this Powder comes, any way, to feel such a degree of Heat as suffices strongly to rarify and expand the aqueous and aerial Particles, they burst with violence from their Prisons, and scatter the dusty Particles of the Gold around.

## Experiment III.

### *The production of Heat and Fire, by the mixture of Sulphur and Iron-Filings.*

20. We took two Pounds of clean Iron-Filings, and as much common Brimstone, and beating them together for some time, in a Mortar, with the addition of Water, we brought the whole to a kind of Paste; which being close prest into an earthen Pot, and set in a Chimney, it in a short time begun to grow hot, and at length took fire. *The firing Mixture of Iron and Sulphur explained.*

21. This mixture never fails to take fire, if the quantity be large; but if it be small, the Paste only heats and cracks, in several places, so that hot Vapours issue out thereat. But if the Heat continues sufficiently long, the whole Mass will be changed into one uniform substance; which, being ground and boiled in Water, affords good Vitriol of Iron *: Whence it is manifest, that the Acid naturally contained in the Brimstone enters the Body of the Iron, and dissolves it. This action may therefore be the cause of the effect; especially if we consider that Sulphur consists of an unctuous or inflammable,

* See below § 26.

mable, as well as an acid part: For this inflammable part of the Sulphur, doubtleſs, takes fire in the violent conflict betwixt the Iron and the Acid of the Sulphur.

*And applied.*

22. This Experiment, if duly attended to and applied, may, in the uſual way of Philoſophers, *account* for ſeveral Phænomena of Nature; ſuch as burning Mountains, ſubterraneous Fires, Earthquakes, hot Baths, *&c.* Thus, for inſtance, as there are large quantities of Iron, Stone, and Sulphur, found in the Bowels of the Earth; as alſo Marcaſites, which are a mixture of the two; when theſe come to be wet, as they may, on many occaſions, with Water, 'tis eaſy to conceive, that they muſt heat, ſwell, ferment, explode, and yield a hot Steam or Vapour, which forcing its way through certain Caverns of the Earth, ſhall produce Earthquakes, or violent Strugglings, of longer or ſhorter duration, till the force finds vent, or expires through ſome Cranny into the Atmoſphere. Sulphureous Vapours certainly abound in the Bowels of the Earth, and ferment, and conflict with Minerals, ſo as to take fire, and make ſudden Coruſcations, or Exploſions; and if confined in the Caverns of the Earth, ſometimes burſt and ſhudder thoſe Caverns to pieces. At which time the hot Vapours, generated by the Exploſion, and expiring through the Pores of the Earth, may raiſe Tempeſts and Hurricanes, or make the Ground ſink into Chaſms, or the Sea boil up in certain places. Theſe ſulphureous Vapours at other times aſcending into the Atmoſphere, may there ferment along with other matters, take fire; and thus occaſion Thunder, Lightning, the *Aurora Borealis*, and other fiery Meteors: At leaſt this ſeems one probable

probable cauſe of ſuch effects, and has a foundation in Nature *.

## Experiment IV.

### *Coruſcations produced by means of Oil of Vitriol and Iron.*

23. We took a cut Body, capable of holding two or three Quarts; and put into it three Ounces of Oil of Vitriol, and twelve of common Water; then warming the mixture a little, we threw in, at ſeveral times, two Ounces, or more, of clean Iron-Filings; upon which an Ebullition, and white Vapours, aroſe; then preſenting a lighted Candle to the Mouth of the Body, the Vapour took Fire, and at the ſame time afforded a bright Fulmination, or Flaſh like Lightning. The Candle being ſeveral times applied, in the ſame manner, afforded the like Coruſcation; during which we ſometimes found the Glaſs filled with a Flame that reached, and circulated, to the bottom of the Liquor; and ſometimes the Flame only roſe into the neck of the Glaſs. *Artificial Coruſcations.*

24. This Experiment will not ſucceed, unleſs the Oil of Vitriol be largely diluted with Water, to make the Menſtruum fit for diſſolving the Metal. 'Tis alſo requiſite to heat the Liquor a little, in order to promote the Solution, that the Vapour may aſcend the freer: But if the Liquor be too hot, the Vapour will riſe too faſt; and ſo, when the Candle is applied, only take fire in the neck of the Glaſs, without making any remarkable Fulmination. *Cautions.*

25. This

* See Sir *Iſaac Newton's Queries*, at the End of his *Optics*; and M. *Lemery's* Paper upon the Subject, in the *French Memoirs*.

*Rationale.* 25. This Experiment appears to have a great affinity with the preceding, and to depend upon nearly the ſame principle: the Oil of Vitriol being a very powerful Acid, correſponding to that of Brimſtone; and Iron, in itſelf, containing ſomething that is properly ſulphureous, or inflammable. It ſhould ſeem, however, that it is not the Sulphur of the Iron alone, but that ſome ſulphureous part of the Oil of Vitriol alſo contributes to the effect; for Spirit of Nitre, or *Aqua fortis*, being uſed in this caſe, produce no Fulmination: But the Spirits of Salt, of Sulphur, and of Allum, which are all ſulphureous, have here the ſame effect as Oil of Vitriol.

*Diſcovery and Uſe.* 26. The Experiment ſeems to have been accidentally diſcovered, by inadvertently approaching a Candle near the mouth of the Glaſs, whilſt Iron was diſſolving in diluted Oil of Vitriol, in order to make the common Vitriol of Iron; for if what remains in the Glaſs after the Fulmination is over, be boiled, filtred, evaporated, and cryſtallized, it affords this Vitriol in great perfection, like what we before obſerved of the mixture of Iron-Filings and Sulphur*.

27. We would recommend it to the curious in Chemiſtry, to endeavour to collect, and, if poſſible, to condenſe, a quantity of the ſulphureous Vapour generated in the preſent Experiment: For this Vapour has not the fetid ſmell of Brimſtone; but is, perhaps, ſomewhat like that volatile, aerial Spirit, which gives virtue to certain mineral Waters †.

EXPERI-

* See above § 22.

† See *Hoffman* of Mineral Waters.

## Experiment V.

### *Fire and Flame produced by the Mixture of two cold Liquors.*

28. We took two Drams of ſtrong and freſh Spirit of Nitre, prepared with Oil of Vitriol, and putting it into a clean and dry four Ounce Gally-Pot, we ſet it under a Chimney; then immediately, and at once, poured to it a Dram of the true eſſential Oil of *Indian* Cloves; and there was inſtantly produced a loud Noiſe, a violent Conflict and Ebullition, with a conſiderable Flame; which being extinguiſhed, a reſinous Subſtance, or actual Roſin, was found at the bottom of the Gally-Pot. *Oil of Cloves and Spirit of Nitre mixed.*

29. To render this Experiment ſafe, (1) it ought to be performed under a Chimney that may carry up the offenſive Vapour; (2) the Oil ſhould be poured from a Vial fixed at the end of a Stick, to prevent any of the fiery matter from flying upon the Operator: And to render it ſucceſsful, (1) the Spirit of Nitre ſhould be ſtrong, and freſh drawn; (2) the Veſſel wherein the Mixture is made ſhould be large, that the Matter may have room to ſwell; (3) the Oil ſhould be poured in at once, to make the more expeditious Mixture; laſtly, the Gally-Pot ſhould be perfectly dry, the Oil genuine, and the Spirit ſtrong, and new drawn. *Cautions.*

30. This Experiment is neither confined to one certain Oil, nor to one certain Acid; the diſtilled Oil of Saſſafras, Guajacum, Box, *Jamaica* Pepper, Cinnamon, or even the empyreumatic Oils of Hartſhorn, Blood, *&c.* will ſerve the purpoſe; or, in general, any thin, eſſential Oil, thickened with Balſam of Sulphur, *&c.* For *Extended.*

ſome

ſome degree of thickneſs or tenacity in the Oil ſeems a primary requiſite, to make it explode with Spirit of Nitre; and for acid Spirits, Oil of Vitriol, and moſt of the other acid Spirits highly rectified, will produce Flame with the aromatic *Indian* Oils, if unadulterated.

31. The Experiment is made to give the greater ſurprize when Gunpowder is fired by pouring a cold Liquor upon it; for if Gunpowder were put to the Oil, this alſo would be fired, upon pouring in the Spirit of Nitre. Hence it may ſeem ſtrange that Camphire, which is an exceeding inflammable Subſtance, ſhould not take fire when added to the Oil, and treated as the Gunpowder. The reaſon ſeems to be that Camphire contains an Acid; and therefore when diſſolved in the Oil, ſomewhat anticipates or leſſens the force of the Spirit of Nitre that is afterwards applied; ſo that the Shock betwixt the two is not now great enough to produce Flame: For in the Shock, or violent Conflict betwixt a ſtrong Acid and a thick Oil, diveſted of Acid, the Fire and Flame in the Experiment appear to be produced.

*And accounted for.*

*Its Force in vacuo.*

32. Nor is the effect leſſened when the Experiment is performed *in vacuo*; where half a Dram of Oil of Carraway-Seeds, and a Dram of Spirit of Nitre, have made a Flaſh like Gunpowder, and burſt the exhauſted Receiver, a Glaſs ſix Inches wide, and eight deep *. This is a very extraordinary effect; as differing from moſt other flaming Bodies, which rather deſtroy than generate Air: But there muſt be a large quantity of Air, or ſomething of equal force, generated by the exploding Mixture, in order to balance and over-power the external preſſure

which

* See Sir *Iſaac Newton's Queries* at the End of his *Optics*.

which in this caſe was ſeveral hundred weight. Hence it ſhould ſeem that the force of our explo-ſive Mixture is much greater than of Gunpow-der; which will not explode *in vacuo*, nor, with the aſſiſtance of the Air, produce any thing like ſuch an effect. It may therefore be worth con-ſidering, whether ſo great a power could not be applied to ſome uſeful purpoſe. The mix-ture might be made cheap, by uſing any of the groſs and ponderous empyreumatic Oils, in-ſtead of the eſſential kind.

## Experiment VI.

### *The liquid* Phoſphorus *of Urine.*

33. We took half a Dram of Camphire, and ground it in a Glaſs Mortar, with three Grains of the ſolid *Phoſphorus* of Urine; then added as much eſſential Oil of Cloves as ſerved to reduce the whole to a fluid form. The mixture thus made may be rubbed upon the Cloaths, the Hair, or the Hands, without danger of burn-ing *. *Solid Phoſphorus made harmleſs.*

34. Chemiſtry hath ſcarce afforded any thing more ſurprizing than the common *Phoſphorus*. To ſee Letters traced with this matter become luminous in the dark, Images and the Bodies of Men to blaze with Light, and abundance of the like Experiments, performed by means of *Phoſ-phorus*, made many perſons curious to know how it was prepared †. The preparation indeed ſeems even to this day kept as a gainful Secret in few hands; and the matter ſold at a very great price: Whence we apprehend it would be of *Hiſtory of Phoſphorus.*



* See below § 43. (11)

† See M. *Homberg*'s Papers on the Subject.

ſingular ſervice to Chemiſtry, to render this commodity cheaper, and diſcover its farther uſes.

35. With this view we ſhall here touch a little upon the Hiſtory of this *Phoſphorus*, commonly called *Kunckell's Phoſphorus*, or the *Phoſphorus* of Urine. It was diſcovered by accident: One *Brand*, an obſcure Chemiſt of *Hamburgh*, ſtumbled upon it as he was ſearching after the Philoſophers Stone; which he firmly believed lay concealed in Urine. This Subject therefore he tortured a thouſand ways; and at length, after a violent Diſtillation, found a ſhining matter, ſince called *Phoſphorus*, in his Receiver. This Matter was ſhewn to Dr. *Kunckell*; but the Proceſs was concealed from him. Soon after this *Brand* died; and *Kunckell* reflecting that *Brand* worked wholly upon Urine, he continued to work upon the ſame Subject himſelf for four years together; and at length, in the year 1679, found the thing he ſought after. Doctor *Kraft* has uſually paſt for the Inventor of this *Phoſphorus*; he being the firſt that carried it abroad; though he only diſtributed it for Dr. *Kunckell*; *Kraft* being at that time unacquainted with the Preparation.

*The ſolid Phoſphorus, how made.*

36. The ſucceſsful method of making it is this; Evaporate any quantity of freſh Urine over a gentle Fire, to a black, and almoſt dry, Subſtance; then with two Pounds thereof thoroughly mix twice its weight of fine Sand: put the Mixture into a ſtrong coated Retort of Stone; and, having poured a Quart or two of clear Water into a large Receiver with a long Neck, join it to the Retort, and work in a naked Fire: let the Heat be ſmall for the two firſt hours; then increaſe it gradually to the utmoſt violence. And continue thus for three or four hours

hours ſucceſſively: At the expiration of which time there will paſs into the Receiver a little Phlegm and volatile Salt, much black fetid Oil, and laſtly the matter of the *Phoſphorus* in form of white Clouds; which either ſtick to the ſides of the Receiver like a fine yellow Skin, or fall to the bottom in form of a ſmall Sand. Now let the Fire go out; but take not away the Receiver before 'tis cold, for fear of ſetting the *Phoſphorus* on fire, by admitting the Air. To reduce theſe ſmall grains into one piece, put them into a little Tin Ingot-Mould, along with Water; heat the Ingot, to make the Grains melt together; then add cold Water, till the matter is congealed into one ſolid Stick, like Bees-Wax; which being cut into little pieces fit to enter the mouth of a Vial, may be preſerved by Water, and keeping the Glaſs cloſe ſtopped. If the Glaſs were not to be ſtopped, the *Phoſphorus* would turn black on its ſurface, and at length be ſpoiled.

37. The Cautions required to make the Pro- *Cautions.*
ceſs ſucceed are, (1) to evaporate the Urine, while it is recent; (2) to prevent its boiling over, and ſo loſing the moſt unctuous part; (3) to let the matter afterwards ferment in the cold; (4) to mix the black matters with Sand, to prevent its melting and running together; (5) to uſe a Stone Retort, thoſe of Earth being too porous, and ſuffering the *Phoſphorus* to tranſude ſooner than paſs into the Receiver; (6) to have the Receiver very large, and with a very long neck, to prevent its breaking and overheating; which would either evaporate the white Vapour wherein the *Phoſphorus* conſiſts, or elſe prevent its coagulating; (7) to put Water into the Receiver, for keeping it cool, and quenching the *Phoſphorus*, as it falls to the bottom;

(8) to make the Fire ſmall at firſt, that the Retort may be preſerved, and the black matter graduaiiy dried; which would otherwiſe ſwell and come over in a black Froth: *Laſtly*, 'tis found neceſſary, that the Urine for the Operation be of ſuch as uſe Malt-Liquors, rather than Wine. All theſe circumſtances being required for obtaining the *Phoſphorus* to advantage, no wonder if ſo many of thoſe who attempted it miſcarried.

*The Proceſs ſhortened.*

38. This Operation may be greatly ſhortened, by freezing and concentrating freſh Urine; afterwards evaporating it, with care; then digeſting it *per ſe* in the manner above mentioned. When thoroughly digeſted, commit the matter, in a large quantity, to an Iron Pot, with an earthen Head, as the Chemiſts uſually do for making Spirits of Hartſhorn, or the Spirit and Salt of Urine: And when thus all the Salt and Oil are obtained, let the *Caput mortuum* be taken out, and mixed with twice its own weight of Alum. The Matter may now be put into a well coated Long neck, and worked with care, in a Reverberatory-Furnace, into very large Receivers, filled with Water, and connected to the Long necks by Adopters; the lower ends whereof may enter the Water, as in diſtilling of Quickſilver; the Operation being continued for eight or ten hours. And this we apprehend to be the beſt way hitherto known of procuring *Phoſphorus* to advantage. Dr. *Wall* informs us, that Mr. *Boyle*, being concerned to find how ſmall a proportion of *Phoſphorus* was afforded by Urine, deſired him to look out for another Subject that might afford it in greater plenty. The Doctor afterwards cauſing a piece of dry matter to be dug up in the Fields where Night-men emptied their Carts, he obſerved a great number

ber of ſmall particles of *Phoſphorus* therein. This Matter the Doctor immediately carried to Mr. *Boyle*; who ſet *Bilgar* the Chemiſt to work upon it: But he could obtain very little *Phoſphorus* from it, till another Material was added to it, in Diſtillation; and then he procured *Phoſphorus* in ſuch plenty, that, ſelling large quantities at ſix Guineas the Ounce, he ſoon became rich, and left *England**. The matter which thus fixes and increaſes the *Phoſphorus*, we apprehend to be Alum; which is itſelf not only in ſome meaſure prepared from Urine, but appears to afford the ſame kind of Acid that *Phoſphorus* yields by burning: For upon its Analyſis, *Phoſphorus* appears to be a compoſition of a ſtrong Acid and an inflammable Matter, exactly in the manner of common Brimſtone; whence it may not improperly be called an *animal Sulphur*: And accordingly, like common Brimſtone, it will burn under a Glaſs Bell, and afford Flowers, that become an acid Liquor, like *Oleum Sulphuris per Campanam*, by attracting the moiſture of the Air.

39. And in this manner it has been uſed, ſo as to produce extraordinary changes upon Metals, eſpecially in the philoſophical view; the Acid it ſelf, even without Heat, proving a Menſtruum to perhaps all the Metals. But when this Acid is driven into the Pores of the Metal, by the action of the Flame in burning the *Phoſphorus*, it ſeems productive of much greater effects; as is known to thoſe acquainted with the ſublimer Metallurgy. And it is principally with a view of promoting this kind of Experiments, that we have beſtowed ſo much of our Lecture upon facilitating the method, and eaſing the expence, *Farther Uſes.*



* See the *Philoſophical Tranſactions.*

of preparing this *Phoſphorus*; which of all the kinds hitherto diſcovered ſeems the moſt uſeful.

*Other kinds of Phoſphori.*

40. This *Phoſphorus* has been ſeveral ways diſguiſed, ſo as to make it appear under various forms; ſometimes as a Solid, ſometimes as a Liquid, ſometimes as an Ointment, ſometimes as a running Mercury. There are alſo others of different kinds; of which we ſhall only mention two, diſcovered by M. *Homberg*; the firſt is that uſually called the *Black Phoſphorus*, now commonly prepared with Alum and Wheat Flower, by taking four or five parts of Alum to one of Wheat Flower, and calcining them together to a brown or blackiſh Maſs; which being powdered, and put into a Vial, ſet, looſely ſtopped with Paper, in a Sand-heat, ſo as to continue glowing hot for ſome time; then removing the whole from the Fire, and ſuffering it to cool gradually, and at laſt ſtopping the Bottle cloſe. A little of this Powder being poured out of the Bottle, and expoſed to the open Air, immediately takes fire, and appears like a glowing Coal. But the Powder muſt be freſh made, to have a ſtrong effect: For the Sun's Rays, or the moiſture of the Air, being gradually admitted to it, deſtroy its virtue; whence it ought to be kept in a dark and dry place. 'Tis remarkable of this *Phoſphorus*, that it may be made almoſt from any animal or vegetable Subſtance, inſtead of Wheat Flower; but that no Salt whatever can be ſubſtituted inſtead of Alum.

*The black Phoſphorus.*

*The Phoſphorus of Sal Ammoniac and Lime.*

41. M. *Homberg*'s other *Phoſphorus* is made of one part Sal-Ammoniac, and two parts Lime, flaked in the Air; theſe being mixed well together, a Crucible is to be filled with them, and ſet in a ſmall Fire of Fuſion; where, as ſoon as the Crucible becomes red hot, the Mixture will melt, and ſhould be ſtirred with an Iron Rod,

to

to prevent its running over. When the matter is entirely fuſed, it may be poured into a Braſs Mortar; and when cold, 'twill appear of a grey Colour, and almoſt as if it were vitrified. If now it be ſtruck upon with any hard body, it appears as on fire in the whole extent of the Stroke; but the Matter being brittle, it may be proper, for the Experiment's ſake, to dip little Bars of Iron, or Copper, into the melted Matter in the Crucible; for thus they will be enamelled, as it were, with the Matter; and theſe Bars may be ſtruck upon, ſo as commodiouſly to repeat the Experiment ſeveral times before the Matter falls off. The Bars are to be kept in a dry place, to prevent the *Phoſphorus* upon them from running, by the moiſture of the Air.

*Diſcovery of* Phoſphori *accidental.*

42. Both theſe *Phoſphori* were diſcovered by accident: The firſt was obtained by ſearching for a limpid Oil, from the common ſtercoracious matter, that ſhould fix Quickſilver; and the ſecond, by endeavouring to calcine Sal-Ammoniac with Lime, ſo as to render it fuſible like Wax; which end was obtained, but not the other.

43. There have been no very conſiderable uſes of theſe two *Phoſphori* hitherto diſcovered; but the *Phoſphorus* of Urine has been employed for making many curious Experiments; a few whereof we ſhall here exhibit.

*Experiments with the Phoſphorus of Urine.*

(1) The Light of this *Phoſphorus* appears greater *in vacuo* than in the open Air.

(2) In hot weather it is obſerved to dart Flaſhes of Light through the Water wherein 'tis contained, ſo as exactly to reſemble Lightning; which thus darts unextinguiſhed through watery Clouds and Vapours.

(3) Theſe Flaſhes of Light are not apt to kindle or burn any combuſtible matter, in which they reſemble the harmleſs kind of Lightning; but in a condenſed ſtate this *Phoſphorus* burns very furiouſly, and with a moſt penetrating Fire, ſo as to melt and diſſolve Metals: In which reſpect it again reſembles the more deſtructive kinds of Lightning, which are found to have the ſame effects.

(4) If a little piece of this *Phoſphorus* be viewed through a Microſcope, the internal parts appear in a conſtant Ebullition.

(5) A little piece of it being put into a Silver Spoon, and held over the Fire, it burſts out into a ſhining Flame, leaving a red ſpot in the Spoon, of a corroſive, acid taſte; and being diluted with Water, the mixture makes a conflict with Oil of Tartar *per deliquium*.

(6) If a little of it be ground in a Glaſs Mortar, with twenty times its own weight of Nitre, it does not take flame, but only diſperſe a ſhining property through the Body of the Nitre; but if ground in the ſame manner with Iron-Filings, reduced to Powder, a bright Flame immediately enſues.

(7) Though this *Phoſphorus* appears to be a kind of Sulphur; yet it does not diſſolve in high rectified Spirit of Wine, but communicates ſome ſulphureous parts thereto: For if this Spirit be poured to Water in the dark, it yields a faint degree of Light.

(8) The nature of this *Phoſphorus* is conſiderably changed, by being long digeſted with Alcohol: For thus it becomes a kind of white tranſparent Oil, that does not coagulate without an extreme degree of cold, nor afford any manner of Light; and when freſh Spirit of Wine

Wine is poured thereon, it does not, like other Oils, mix therewith, nor diſſolve therein.

(9) If this *Phoſphorus* be ſeparated from the Spirit of Wine wherewith it was digeſted, and be afterwards well waſhed in common Water, it, by degrees, recovers its former conſiſtence, and coagulates into a tranſparent matter, whiter than before; but neither affords ſo much light, nor recovers its primitive ſhining virtue, nor its yellow colour.

(10) The Spirit of Wine ſo ſeparated becomes yellowiſh, and ſmells ſtrong of the *Phoſphorus*; though it ſhines not, except when poured upon Water.

(11) This *Phoſphorus* being mixed with a large quantity of Pomatum, makes, as well as with Camphire and the Oil of Cloves, a ſhining Unguent, that may be rubbed on the hands and face, without danger of burning, ſo as to render them luminous in the dark.

(12) If a piece of Paper, or Linen, be dipt at one end in Spirit of Wine, and a bit of *Phoſphorus* be cruſhed on the other end that remains dry, the Spirit will be fired by the *Phoſphorus*, without immediate contact: But the ſame thing will not happen, if the Paper were dipt in Oil of Turpentine, nor if a bit of *Phoſphorus* were rubbed upon the end dipt in the Spirit of Wine; only when the Spirit is entirely evaporated the *Phoſphorus* will burn, though with difficulty, and ſlowly.

44. There are many of theſe odd kind of Experiments that might be made with *Phoſphorus*; which is a Subſtance that ſeems, in Chemiſtry, to be much ſuch a thing as the Loadſtone in Natural Philoſophy; and its effects almoſt as odd and difficult to explain, for want of knowing the latent properties of Bodies.

AXIOMS

## AXIOMS and CANONS.

1. We learn from the preceding Experiments, That Gunpowder, and the Arts thereon depending, are capable of farther improvement; and that more forcible and deſtructive inventions than thoſe at preſent in uſe are diſcoverable, if required *.

2. That, in particular, great uſe may be made of compreſſed Air in this way, the mixture of Iron-Filings and Brimſtone, in large quantities; the *Pulvis* and *Aurum fulminans*, Salt of Tartar; the mixture of certain cheap Oils and acid Spirits, for producing extremely powerful and deſtructive effects †.

3. That many natural Phænomena, ſuch as Earthquakes, Thunder, Lightning, Vulcanoes, the *Aurora Borealis*, Hot Baths, *&c.* are imitable and explicable by chemical Experiments; particularly Mixtures, and exploſive Powers ‡.

4. That Fire and Flame are producible by the ſimple mixture of appropriated Bodies, if made with ſufficient violence; or that Oils freed of their acid part, and ſuddenly joined with ſtrong acid Spirits, are inſtantaneouſly productive of Fire and Flame **.

5. That by this action, or the intimate and ſtrong union of acid Spirits with Oils, Roſins are producible ††.

6. That very violent Exploſions may be made *in vacuo*, as well as in the open Air ‡‡.

7. That the *Phoſphorus* of Urine is applicable to many extraordinary purpoſes; particularly to the introducing of uncommon changes in metalline Bodies *†.

8. That

* See Exp. I. II. and V. † Exp. I. II. III. V. ‡ Exp. III. IV. V. VI. ** Exp. V. †† ib. ‡‡ ib. *† Exp. VI.

8. That as moſt Diſcoveries of chemical Exploſions and *Phoſphori* were accidental, greater things may be expected from a ſagacious Experience, conducted by Reaſon, and by a farther diſcovery of Cauſes and Axioms*.

9. That the *Phoſphorus* of Urine may be made in large quantities, and with ſmall expence; ſo as to afford deſirable opportunities for the farther improvement of Chemiſtry and Metallurgy †.

10. That there may be many latent properties in Bodies, remaining unknown to us, for want of making the proper Experiments; which alone can diſcover, and bring thoſe properties to light.

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* See Exp. I. II. III. IV. V. VI. † Exp. VI. ‡ Exp. I. II. III. IV. V. VI.

LECTURE

# LECTURE XX.

CONTAINING

*Ways of applying* Chemiſtry *to the farther Service and Improvement of* Natural Philoſophy, Arts, Trades, *and* Buſineſs.

## I.

*Deſign.*

1. OUR preſent Lecture is intended to ſhew ſome particular ways of extending and applying Chemiſtry to the farther improvement of Natural Philoſophy, Arts, Trades, and Manufactures: For though this be the general Deſign of our whole Courſe; yet we judge it proper to beſtow our laſt Lecture expreſsly upon the Subject. We ſhall therefore, (1) divide Chemiſtry into its ſeveral Branches, and ſhew how each of them may be farther improved; (2) exhibit a ſet of Experiments tending to that end; and (3) offer a few Rules for its farther application and enlargement.

*Chemiſtry divided,*

2. *Chemiſtry*, in general, may be uſefully divided into Philoſophical, Technical, Commercial, and Oeconomical Chemiſtry.

*Into Philoſophical,*

3. By *Philoſphical Chemiſtry* we underſtand Chemiſtry practiſed in Miniature, after the manner of our preſent Courſe; ſo as to diſcover the Cauſes of phyſical Effects, and to make new Diſcoveries in Nature *.

4. By

* See below § 7.

4. By *Technical Chemiſtry* we underſtand the application of Philoſophical Chemiſtry to the immediate ſervice of an Art; ſo as to invent, form, aſſiſt, promote, or perfect it in the large way of buſineſs. *Technical,*

5. By *Commercial Chemiſtry* we mean the application both of Philoſophical and Technical Chemiſtry to the eſtabliſhing, ſupporting, and improving any Branch of Trade or Commerce. *Commercial,*

6. And by *Oeconomical Chemiſtry* we mean the application of Philoſophical, Technical, and Commercial Chemiſtry to the ſervice and accommodation of a Family. *And Oeconomical.*

7. Philoſophical Chemiſtry conſiſts of three parts; *viz. Invention, Rationale,* and *Experiment:* Whence we may define it a particular Exerciſe of the rational and inventive Faculties of the Mind, leading to Experiments, and thence to the diſcovery of Cauſes; ſo as to form Axioms, that ſhall rationally account for Phænomena, and diſcover Rules of Practice for producing uſeful effects. And thus Philoſophical Chemiſtry is not only a Key to all the other parts, but of itſelf diſcovers the Cauſes of many natural Phænomena; as particularly Earthquakes, Vulcano's, Vegetation, the growth of Minerals, *&c.* *Philoſophical Chemiſtry; its Parts:*

8. This Branch of Chemiſtry alſo explains the general forms and qualities of Bodies, whereon their properties and effects depend; as Volatility and Fixedneſs, Fluidity and Firmneſs, Colours, Taſtes, Odours, Effervеſcences, Fermentations, Solution, Precipitation, Congelation, Extraction, and the like. *Its Office.*

9. To this part of Chemiſtry it likewiſe belongs to bring new inventions to the teſt, ſo as to diſcover their validity or inſufficiency: Thus when any hint is ſtarted for a new Trade, or method

method invented for the improvement of an old one, before any attempt is made to apply it in the larger way, the proper Aſſay or Experiment muſt firſt be performed in Miniature; where if it prove ſucceſsful, this may rationally encourage the erecting of ſuch a diſcovery into an art, or its application to the improvement of buſineſs.

*Illuſtrated.* 10. To have an example of this whole Procedure, we need but reflect upon the general office of the Aſſay-Maſter; who before-hand diſcovers, in Miniature, the quantity of Metal contained in any Ore aſſigned; thereby giving a direction to the Operator at the larger Furnace. And thus Philoſophical Chemiſtry plays directly into the hands of the Technical, Commercial, and Oeconomical ſpecies.

*Its Improvement, by a portable Laboratory.* 11. But before it can do this to the beſt advantage, there are ſeveral deficiencies therein that require to be ſupplied: And firſt, the Labour, Time, and Expence neceſſary to procure the proper Furnaces, Veſſels, Utenſils, and Subjects, for the ready and commodious exerciſe of this Art, have been a great hindrance to its advancement. Upon which conſideration we have endeavoured to collect together a commodious *Philoſophical Laboratory* in a portable form, attended with as many conveniencies as the nature of the thing will allow *.

*By practiſing it, without Fire or Furnace:* 12. In our Definition of Chemiſtry †, we endeavoured to avoid the common error of confining this Art to the ſole uſe and application of Fire. We hope to have ſhewn ‡, that it has a right to employ the other Elements, Air, Water, and Earth; to which we may add Cold and

* See the Eſſay for introducing a Portable Laboratory.
† Lect I. *in init.* ‡ Lect. I. II. III. IV.

and various kinds of Motion. And if it be remembered, that Chemistry is the Art of analysing and compounding Bodies by means of all the Instruments we can procure; an attempt to introduce ways of working in the Art without Fire or Furnace, will not appear surprizing.

*Particularly by means of Cold.*

13. Nay, if a due estimate were made, and the full scope and extent of Chemistry considered; a large and curious part of it would appear to depend more upon other things, than upon the direct use of Fire: Thus, for example, the whole of Fermentation and Putrefaction, two expensive Operations in Nature and Art, are performable without the use of either Fire or Furnace. Farther, the action or instrumental efficacy of Air, Water, and Earth, might, with regard to chemical Operations, be opposed to the action of Fire; which has still a more direct Antagonist, or rather Correlative; *viz.* Cold; whose efficacy in Chemistry is extremely great, and separates the more useless and aqueous parts of Bodies from those that are more spirituous and essential; as we see in the Concentration of Wines, Vinegars, and other spirituous and saline Liquors, by Frost *.

*Chemistry improveable by collecting the Experiments and Practices of Artists.*

14. There is farther wanting to the improvement of *Philosophical Chemistry*, a Collection of all that is hitherto known and practised in the Art, to shew the present state and condition thereof. And this, perhaps, would make no very large Volume; for the original experimental Writers are very few, in comparison of the Collectors and Transcribers: But the more useful part of such a Work is not to be found in Books; and can only be had from observing, collecting,

* See the last of three Essays in Artificial Philosophy, or Universal Chemistry, *Ann.* 1731.

collecting, and digesting the daily practices of mechanical Operators; such as Refiners, Assay-Masters, Smelters, Dyers, Sugar-bakers, Soap-boilers, &c. And till the Secrets and Mysteries of these Arts are known to the chemical Philosopher, he will want many things that are necessarily required to the improvement of Philosophical Chemistry.

*A List of Desiderata.*

15. The last particular we shall at present intimate, as wanting for the exercise and improvement of Philosophical Chemistry, is a List of the Chemical *Desiderata* in all Arts and Trades, in order to procure the readiest ways of supplying them: For such a List would contain so many Problems for the Philosophical Chemist to solve.

*Technical Chemistry divided.*

16. We now proceed to *Technical Chemistry*; which, for the sake of use and commodiousness, we divide into four parts; as it relates to Subjects of the animal, vegetable, and mineral Kingdoms; or to several of them at once. Thus under animal Arts comes the Art of preparing Size and Glue, Tanning, Ivory-Staining, the Dying in Wool, Silk, &c. Under vegetable Arts comes the Art of Timber, or the ways of preserving it sound against the injuries of the Weather, the Sea, &c. the Art of making Rosin, Pitch, Oil of Turpentine, Charcoal, Pot-Ash, &c. the Art of Brewing, and Fermenting for Wines, Vinegars, &c. the Art of Sugar-making, and Refining; the Art of Soap-making, &c. Under mineral Arts come the Arts of Salt, Copperas, Vitriol, Borax, Pottery, Metals, Foundery, Smithery, &c. And lastly, under mixed Arts comes the Art of Paper, the Art of Ink, the Art of Japanning, the Art of Glass, the Art of Pigments, the Art of Pharmacy, the Art of Fire-Works, &c. all which

which are proper chemical Arts, that fall under Technical Chemiſtry.

17. It were eaſy to give a Catalogue of a large number of new, and probably advantageous, Arts or Trades, that might be ſet up in *England*. Thus, for inſtance, we would recommend the introduction of *Engliſh* Arracks and Brandies; which might be ſo plentifully afforded by the Tappings of our Trees, and all kinds of Summer-Fruits: Nor need Wines themſelves, even from the Grape, be here excepted; eſpecially as we have an excellent method of improving all poor and thin Vines, by adding fine flavourleſs Sugar in the Fermentation *. *How to be improved.*

18. We have endeavoured to ſhew, in the preceding Lectures, that many of our Trades are improveable; particularly Brewing, Diſtilling, Soap-boiling, Pharmacy, Minerology, Metallurgy, *&c.* And for new Trades, that the refining and making of various Commodities may be as advantageouſly practiſed in *England* as elſewhere: And among theſe may be reckoned the refining of Borax, Camphire, Tartar, coarſe Manna, *&c.* the making of Salt-Petre, the obtaining of Sulphur, the making of blue Vitriol, Porcellane, new artificial Gems, and numerous other Commodities of Price and uſe.

19. The great thing wanting, to the advancement of Arts, and the perfection of this whole Affair, ſeems to be the joint concurrence of certain Perſons, who ſhould contribute to the carrying of it on. The compaſs of knowledge allotted to a ſingle man or two, bears no proportion to that required for the due conducting of this Work: Nor, perhaps, is the knowledge in being, of the kind here principally required.



* See the Lecture upon the Subject.

Arts and Sciences must chiefly receive their improvements from *physical Knowledge*; that is, a Knowledge drawn from the nature of things: Which can only be acquired by conversing with natural Bodies, observing their properties, and the putting of Bodies together, and separating them again. And this general Process is to be conducted in the way of a *sagacious Experience*; which is a matter of Judgment, not casual or accidental, but formed upon some certain Principles and Analogy of Knowledge. Thus we see, in ordinary Life, and the practice of Trades, the Men educated to them have an acquired sagacity, or habit of judging, each in his own way; which is a sagacity not usually to be found in Men differently educated. The qualifications therefore required for our present purpose may be termed, *Physical or Chemical Habits of judging about things relating to Arts and Trades*, acquired by some competent Experience, or by being for some time versed in this way.

20. If choice were made of a set of Men so qualified, and Rules given for them to pursue; with due care to register all their Experiments, and form them into *Tables*; from whence some should derive Canons and Axioms, others deduce the more useful things for the service of Arts and Trades, &c. so as to make an uniform and steady business of the whole; there is good reason to expect, that, in the compass of a few years, considerable improvements might be made in the present set of Arts and Sciences.

*Commercial Chemistry divided.*

21. *Commercial Chemistry* consists of three parts; *viz.* (1) the Exercise of all the Chemical Arts, in a large manner; so as to supply more than the demands of a single Country, and afford a surplus of commodities for Exportation and foreign consumption: (2) The various ways of condensing,

ſing, curing, preparing, ſecuring, and fitting natural and artificial commodities for carriage and tranſportation: And (3) the ways of ſupplying the chemical neceſſaries to Voyagers and Travellers, for founding, ſupporting, and improving Trade, Traffic, and Commerce, in different Countries.

22. And thus a knowledge of *Commercial Chemiſtry* will eaſily direct us in *England*, to the Arts that may be extended and improved, ſo as to underſell ſome other Nations at the foreign Markets; provided the Duties and Drawbacks are in our favour: For example; We conceive, that Malt-Spirit in *England* may be produced cheaper and better than in *Holland*; that Wines, Vinegars, Brandies, and Arracks, might be made, either here, or in our own Plantations, as good as, and perhaps cheaper than, in their preſent places of growth and importation; that White Lead, Verdigreaſe, Sal-Ammoniac, Pot-Aſh, Hard Soap, *&c.* might be prepared as cheap and good in *England* as in any other part of *Europe*. *How to be improved.*

23. We are likewiſe inſtructed by *Commercial Chemiſtry*, to reduce Goods to their leaſt volume or bulk for Exportation; and again, to ſecure them from the injuries of the Sea, the Weather, and other accidents. Hence Metals come to be exported inſtead of their Ores, Sugars inſtead of the Juice or Rob of the Sugar-Cane, Salt inſtead of Sea-Water, Raiſins inſtead of Grapes, high Spirits inſtead of low Wines, Pot-Aſh inſtead of refuſe Wood, *&c.* And thus it is that, by means of Technical and Commercial Chemiſtry together, different Countries are ſupplied with Lead, Tin, Iron, Silver, Oil, Tallow, tanned Hydes, Pitch, Roſin, Brimſtone, Wax, Wines, Brandies, Salt, Sugars, Treacle, Paper, *&c.* whereby all Trade,

Traffic, and Commerce, is ſupported. And to diſcover this kind of Contrivances, or Reductions, is the office of Commercial Chemiſtry. Thus, inſtead of importing many Tuns of a foreign dying Wood, we are taught to extract its tinging parts, and bring them away in the quantity of a few Pounds. And to do this more generally, as it might be done, would tend to perfect the Trade of the Dry-Salter, and leſſen the expence of the Dyer.

24. Another advantage of *Commercial Chemiſtry* is, that it affords the neceſſaries for long trading Voyages. Thus, in particular, it directs us to a *Chemical Cheſt*, and a *Portable Furnace*, with its Apparatus of Flux-Powders, for aſſaying Ores; a Skrew-Preſs for Oils, and a Still for examining fermented vegetable Juices. It alſo directs us to the certain Rules of diſcovering the Sophiſtications practiſed in Wines, Brandies, Vinegars, Arracks, Gold Sand, Gold Bars, or Ingots, counterfeit Gems, *&c.* and to the ways of aſſaying Pot-Aſh, Tincal, Ambergreaſe, Musk, and all the Drugs. So that to improve this part of Chemiſtry, little more ſeems required than the bringing it into more general uſe; as it might be to great advantage, if Philoſophical and Technical Chemiſtry were firſt improved to any conſiderable degree.

*Oeconomical Chemiſtry divided.*

25. We now come to our laſt Diviſion of Chemiſtry; *viz.* the *Oeconomical Branch*; which is of great utility and extent; ſo to be capable of improving all the reſt. This Branch we chooſe to divide with regard to the ſeveral offices of a Houſe; wherein, as in ſo many different Laboratories, it may be commodiouſly practiſed: For inſtance, in the Brewhouſe, the Store-Room, the Kitchen, the Dairy, the Laundry, and the Cellar. Thus, by means of

*Oecono-*

*Oeconomical Chemiſtry*, we are inſtructed in the beſt ways of procuring and brewing with Malt, Treacle, Hony, Sugar, or other vegetable Juices; the beſt ways of raiſing and of preſerving Yeaſt, or Wine Lees, for baking or brewing; and of imitating the natural Wines of foreign growth. This Art directs us how to procure the ſimple and compound Waters of Vegetables, in their greateſt perfection; and to make a ſet of Brandies or Cordial Waters, even from the groſs Lees, Sediments, or Bottoms of our Wine or Ale Casks. Hence alſo we learn the methods of preſerving Fruits in Sugar, and ſeveral vegetable Productions, in the way of Pickle, *&c.* The Art of Cookery alſo is by this means improveable: So are all the Dairy productions, and the buſineſs of the Laundry; as by rendering hard Waters ſoft, *&c.* But to ſhew this fully, and to improve the deſign, would require a particular Treatiſe, under the ſeveral Heads of the *Brewhouſe*, the *Store-Room*, the *Kitchen*, the *Dairy*, the *Laundry*, and the *Cellar* *.

II.

26. We now proceed to our Experiments: The firſt whereof will ſhew that Sal-Ammoniac may poſſibly be made to as great advantage in *England* as in the *Levant*; the ſecond will ſhew the method of making a Varniſh of Amber, with a View to improve the Arts of Japanning, Embalming, *&c.* the *third* will ſhew how to make a very hard Glaſs, for improving the Art of Glaſs, Enamelling, and the Buſineſs of artificial Gems; the *fourth* Experiment will ſhew how to prepare a Foil for foliating figured Glaſſes,

*Purport of the Experiments.*



* See the firſt of the three Eſſays in *Artificial Philoſophy*, or *Univerſal Chemiſtry*, publiſhed in 1731.

ſes, and turning them into Speculums; the *fifth* will ſhew a way of making a curious and uſeful Glue; and the *ſixth* and laſt will ſhew a method of giving Copper a Gold Colour, and a greater degree of Ductility, by way of directing an Enquiry after methods of introducing other uſeful changes into Metals.

## EXPERIMENT I.

### *That Sal-Ammoniac may be advantageouſly made in* England.

*Sal Ammoniac prepared.*

27. We took four Ounces of the common volatile Salt of Ox-Bone, and ſaturating it with the ſtrong Spirit of Sea-Salt, evaporated the ſuperfluous moiſture; upon which we found a Cake of true Sal-Ammoniac left behind.

*Uſe of the Experiment.*

28. This Experiment regards both Philoſophical and Technical Chemiſtry; as not only ſhewing that Odours may depend upon the Mechanical Structure or Texture of the parts of Bodies; but alſo leading to a cheap way of obtaining Sal-Ammoniac in other Countries, as well as in the *Levant*.

*In Philoſophical Chemiſtry, or the Doctrine of Odours.*

29. The volatile Salt here employed has a very quick and pungent Odour; ſo likewiſe, though in a leſs degree, has the Spirit of Salt; but theſe two, upon mixing, deſtroy each other's Odour, ſo as to leave the Cake of Sal-Ammoniac ſcentleſs: The reaſon is, that theſe two odorous Liquors loſe of their volatility by mixture; ſo that their fine parts can no longer fly off briskly, and ſtrike the Nerves of the Noſe; whereon all ſmelling depends. But if a little of the Sal-Ammoniac be ground in a Mortar, along with another ſcentleſs, but more fixed, Body, *viz.* an equal quantity of Salt of Tartar; this

Salt

Salt of Tartar laying hold of the Acid of the Sea-Salt, leaves the volatile Salt at liberty to aſcend and ſtrike the Noſtrils briskly, as before: Whence we ſee that Odours may be mechanically produced, and deſtroyed. And the ſame is confirmed by many other inſtances of Philoſophical Chemiſtry; and holds equally of Taſtes.

30. And hence we may derive ſome Rules for improving the Odours of certain Perfumes; or for recovering them when impaired, or almoſt deſtroyed. Thus it is known to Perfumers, that Sugar being ground with Musk or Ambergreaſe, opens the Body thereof, and makes theſe Subſtances go farther in the perfuming of Waters, Powders, or the like: And this the Sugar chiefly does, by attenuating, reſolving, and ſubtilizing the viſcous parts of thoſe Sweets; ſo that they now move freer, and ſtrike the Noſtrils brisker, than before. And when theſe, or other Perfumes, have almoſt loſt their natural Odour, it may in good meaſure be recovered to them by the prudent addition of a little volatile, animal Salt; as that of Hartſhorn. And hence we ſee the phyſical reaſon why decayed Perfumes are ſometimes ſuſpended in a Jakes, to recover their loſt Odour; for all ſuch places abound with volatile Salts, continually ariſing from the Urine, and corrupt animal and vegetable matters, which are therein a ſtate of Putrefaction. *Rules for improving Perfumes.*

31. Sal-Ammoniac is alſo obtainable in *England*, by ſubliming a mixture of Wood-Soot, Urine, and Sea-Salt, after the ſame manner as they do in the *Levant*: But it ſeems more eaſy, and perhaps it might prove cheaper, to prepare it in the way of the preſent Experiment. The volatile Salt for the purpoſe will be abundantly ſupplied by the Pith of Horns, Blood, the refuſe of *Sal-Ammoniac otherwiſe obtainable.*

of a Slaughter-house, putrified Vegetables, &c. and the Spirit of Salt may be made at an easy rate, in a proper Furnace.

*The Experiment extended.*

32. But the present Experiment might prove still more serviceable, by leading to a way of procuring other saline Bodies, besides Sal-Ammoniac: For it should seem that several Salts may be artificially composed by the union of their two constituent parts; as we here see Sal-Ammoniac is. For example; The making of blue Vitriol may be attempted, by boiling Copper, instead of Iron, in the raw Liquor of the Pyrites; from which the common green Vitriol is made. And if this hint were duly pursued, perhaps it might lead to the discovery of several new Arts and Trades.

## EXPERIMENT II.

### *An Amber Varnish.*

*Amber dissolved.*

33. We took four Ounces of Amber, and putting it into a Crucible, just melted it with a small degree of Heat; then poured the fluid Mass upon the Iron Plate. When the melted Matter grew cold, we reduced it to Powder; and adding thereto two Ounces of drying Oil, (that is, Linseed Oil prepared, or thickened, by boiling it with a little Litharge) and one Pint of Oil of Turpentine, we dissolved the whole together into a Varnish.

*Use of the Experiment.*

34. This method of making the Amber Varnish is kept as a Secret in few hands; but deserves to be made publick, as a leading Experiment, to direct the means of perfecting the Arts of Varnishing and Japanning, or the ways of dissolving Amber; whereon the perfection of various Arts may depend. Thus, in particular, the

the Art of Embalming would be highly improved, if we could preſerve the human Corps in a tranſparent Caſe of Amber; as we ſee the Bodies of Flies, Spiders, Graſhoppers, *&c.* are, to great perfection.

35. An uſeful Subſtitute, or Approximation, in this way, has been, by fine Roſin, boiled to Colophony, or a tranſparent and hard, though brittle, Subſtance; which being diſſolved by Heat, and the Bodies of ſome ſmall Animals ſeveral times dipped therein ſucceſſively, they have been thus coated over with Colophony, that in ſome degree reſembles Amber; but requires to be carefully kept from the Duſt, to preſerve its Tranſparency. *Approximation.*

36. But if Amber could be diſſolved without impairing its Tranſparency; or one large Maſs be made of it, by uniting a number of ſmall ones; it would not thus only tend to perfect the Art of Embalming, but likewiſe come to be uſed, on many occaſions, inſtead of Wood, Marble, Glaſs, Silver, Gold, and other Metals: for then various kinds of Veſſels and Utenſils might be commodiouſly made thereof. *Uſes of diſſolving Amber.*

37. To forward the diſcovery, our preſent Experiment ſhews, that Amber contains a certain ſlimy, aqueous, or mucilaginous part, which in the ordinary way requires to be evaporated by a ſcorching Heat, before the Amber will readily diſſolve in Oil; wherewith it afterwards unites into a Subſtance of a nature compounded of that of an Oil, a Gum, and a Roſin: Nor would the thin ethereal Oil of Turpentine diſſolve it, unleſs firſt thickened, and fitted for this purpoſe, by means of the drying Oil. Hence, as it ſeems plainly intimated that Amber is not only reſinous, but alſo mucilaginous, whoever would attempt to melt ſmall pieces of Amber *How to attempt its Solution.*

ber into large ones, might do well to consider the Subject as a mucilaginous Rosin; and therefore fitted to dissolve, (1) in a thick Oil, after a previous evaporation of its aqueous parts, or the destruction of its more mucilaginous nature; (2) that it may possibly be dissolved, by boiling in a Lixivium of Salt of Tartar, or Quicklime; or if any could be found, as there may, still sharper, and more alkaline; and (3) that the Digestor seems well adapted to dissolve this mucilaginous and resinous Substance, by means of an expressed Oil added to the Amber, in fine Powder, and kept from scorching by the interposition of Water. And here we recommend a long and moderate Digestion, rather than a violent Heat. Thus, therefore, there are three methods pointed out to us, by our present Experiment, for dissolving Amber, either without considerably destroying its Texture, or at worst leaving it in a state reducible, by an easy operation, to a kind of Amber again.

## EXPERIMENT III.

### *A harder Glass than the common.*

*Borax Glass.* 38. We took four Ounces of Borax, and an Ounce of fine white Sand, reduced to Powder, and melted them together in a large close Crucible, set in a Wind Furnace, keeping a strong Fire for half an hour; then taking out the Crucible, and, when cold, breaking it, we found at the bottom a pure hard Glass, capable of cutting common Glass almost like a Diamond.

*Use of the Experiment.* 39. We have here an Experiment, which, being duly varied, may lead to some considerable improvements in the Arts of Glass, Enamels, and artificial Gems: It shews us an expeditious method

method of making Glass, without the use of fixed Salt; which has generally been thought an essential Ingredient in Glass; and which is the Ingredient that gives the common Glass its softness. But Borax is a neutral Salt, which, being urged by the Fire, does not turn any way alkaline; but, of itself, without addition, presently runs into Glass. And whether other Ingredients might not here be advantageously substituted for soft Sand, particularly calcined Flints, powdered Crystal, *&c.* we recommend to farther Experience; so as to attempt making a Glass that shall, in some degree, approach the hardness of a Diamond.

40. If a pure transparent Glass, of this degree of hardness, can be tinged in the ordinary manner, by means of the prepared metalline Calces, it should seem that the art of making counterfeit Gems would then have gained its perfection; for the Colours thus introduced are in no respect inferior, but perhaps superior, to the natural colours of the Sapphire, Emerald, Ruby, *&c.* So that nothing more seems wanting to perfect this Art, than the discovery of a dense, hard, crystalline Glass, that shall polish like Crystal, and not scratch in the wear.

*The Experiment extended.*

41. In order to give our Glass the desired degree of hardness, it may be proper to continue it long in the Fire; which is constantly found to add strength and hardness to Glass: Insomuch that common Glass, by being constantly kept in a strong Fusion for a month or six weeks, has become of a stony hardness; a large part of the fixed Salt thus going off in the Fire; and consequently leaving the Glass less charged with Salt, or nearer approaching to the native hardness of the Flint or Sand employed in preparation.

42. If

42. If the uſe of Borax ſhould, in this manner, be found to have a conſiderable effect, it will be proper to enquire farther into its natural and chemical Hiſtory; which ſeems at preſent to be little regarded. Perhaps it were not impoſſible to find this uſeful Subſtance in ſome parts of *Europe*, to imitate it by art, and to diſcover better ways of refining it than thoſe now uſually practiſed.

43. The facility wherewith this Salt runs into Glaſs, or the ſmall degree of heat, and the ſhort time required for that purpoſe, if well attended to, may be capable of enriching Chemiſtry, and more particularly the Hiſtory of Glaſs; at leaſt we have good reaſon to believe that the preſent Experiment is capable of being largely diverſified, and improved to the ſervice of ſeveral Arts.

## EXPERIMENT IV.

### *A Foil for turning ſpherical, or other figured Glaſſes into Speculums.*

*The Silvering Amalgam.*

44. We took half an Ounce of clean Lead, and melted it with an equal weight of pure Tin; then immediately added half an Ounce of Biſmuth, and carefully skimmed off the Droſs: Now removing the Ladle from the Fire, we added, before the Mixture grew cold, five Ounces of pure Quickſilver, and ſtirred the whole well together; then put the fluid Amalgam into a clean Glaſs.

*How to be applied.*

45. When this Amalgam is uſed for Foiling, or Silvering, let it firſt be ſtrained through a linen Rag; then gently pour ſome Ounces thereof into the Glaſs intended to be foiled. The Mixture ſhould be poured into the Glaſs by means of a paper Funnel, reaching almoſt to the

the bottom, to prevent its flying to the ſides; then dexterouſly inclining the Glaſs every way, endeavour thus to faſten the Foil. When this is once done, let the Glaſs reſt for ſome hours; then repeat the operation, till at length the fluid Maſs is evenly ſpread and fixed over the whole internal ſurface; as it may be known to be by viewing the Glaſs againſt the light. And now the ſuperfluous Amalgam being poured out, the outſide of the Glaſs may be poliſhed with Putty, Chalk, or Tripoli, ſprinkled upon a Cloth. And thus the Operation is compleated. In this manner are made thoſe ſhining ſpherical Glaſſes (appearing like Glaſſes filled with Quick-ſilver) which we ſometimes ſee hung up in Parlours, near the Cieling, to invite the Flies in Summer, from the Windows, and other parts of the Room, where they might prove more offenſive.

46. The Operation has conſiderable advantages, as being performable in the Cold; and is not attended with the danger of poiſonous Fumes from Arſenic, or other unwholſome matters uſually employed for this purpoſe. And how far it is applicable to the more commodious foiling of the common Looking-Glaſſes, and other Speculums, may deſerve to be conſidered. *Advantages of the Operation.*

## Experiment V.

### *A curious and uſeful Glue.*

47. We took an Ounce of Iſing-glaſs, beat to ſhreds, and put it into a Pint of Brandy; where, by means of a little heat, or gentle ſimmering over a common Fire, it gradually diſſolved: we then ſtrained the Solution through a piece of fine Muſlin; and thus obtained a Glue, *Iſing-Glaſs Glue.*

Glue, that ſhould be kept in a Glaſs cloſe ſtopped.

*Its Uſes.* 48. This Glue, with a very gentle Heat, diſſolves thin, tranſparent, and almoſt limpid: When uſed in the manner of common Glue, it joins the parts of Wood together, ſtronger than Wood is joined to itſelf; ſo that the pieces thus joined will break in any other part rather than where they are glued. It is alſo remarkable, that if Saw-duſt, or powdered Wood, be made into a Ball with this Glue, the Ball will prove ſolid and elaſtic; ſo that it may be turned and uſed as a Bowl, without breaking. And whether, by means of ſuch a Glue as this, ſomething conſiderable may not be effected in the emboſſing of Wood-work, we leave to farther Experience. The Glue being thus made with Brandy, will keep longer without corrupting; and is therefore a proper form wherein to preſerve Iſing-glaſs ready diſſolved for the fining of Wines, or other uſes.

*Extended.* 49. Another curious uſe of our Glue is, that it ſerves excellently for taking off the impreſſions of Medals, or Coin: Thus if a little of this melted Glue be poured thinly upon a Guinea, ſuppoſe, ſo as to cover the whole ſurface of the Piece, and the Glue be ſuffered to remain thereon for a day or two, till it becomes thoroughly dry, it will appear hard and tranſparent, like a piece of *Muſcovy*-Glaſs, with the impreſſion of a fair Guinea in *Entaglio*, as they call it, on one ſide, and in *Relievo* on the other.

*And improved.* 50. This Glue, therefore, dries into a very ſtrong, tough, and tranſparent Subſtance; not eaſily to be hurt or damaged by any thing but aqueous moiſture, which would ſoon diſſolve it: So that it is not fit to be uſed in any work that muſt be expoſed to wet or weather. But for a

Glue

Glue to ſtand the weather, let choice be made of the common Glue diſſolved with Linſeed-Oil.

51. The natural and experimental Hiſtory of Glue might greatly tend to the improvement of Chemiſtry: For it ſhould ſeem as if all animal and vegetable Subſtances were either originally made up, or might at laſt be reſolved into Glue or Jelly. Doubtleſs a knowledge of the nature of Ropineſs, Viſcidity, Sizineſs, Mouldineſs, *&c.* would give conſiderable light to Natural Philoſophy and Medicine; and leads us farther into the effects, nature, and proceſs of Growth, Fermentation, and Putrefaction. This Enquiry, therefore, ſhould be proſecuted with care; beginning, for example, with that viſcous Subſtance the White of the Egg, or Serum of the Blood, in their natural ſtates; and obſerving how their tenacity is altered, by moderate degrees of warmth or cold. The Enquiry might next proceed to the mucilaginous matter of Snails, Frog-Spawn, Fiſh, and other Animals in Embrio, Vegetables, *&c.* and gradually proceed to Subjects of the mineral Kingdom. And this Enquiry, we apprehend, may be uſefully proſecuted without the aſſiſtance of a chemical Apparatus; ſo as to diſcover the beſt ways of preparing Cements, Glues, Sizes, Jellies, *&c.* for various mechanical and oeconomical uſes. *Hiſtory of Glues wanted.*

## Experiment VI.

### *Copper made more ductile, and turned of a Gold Colour.*

52. Make an Amalgam, of one part pure Copper, and three parts clean Quickſilver; boil

*Copper advanced somewhat nearer to Gold.*

boil the Amalgam in River-Water for two hours; then diſtil off the Quickſilver, and cohobate it once or twice: laſtly, fuſe the Copper that remains in the Retort; and it will be of a Gold Colour, and more ductile than common Copper. This Experiment was not brought to perfection in the Courſe, on account of the difficulty then found of amalgamating the Copper; which was attempted thus: We diſſolved as much Copper in *Aqua fortis* as the Menſtruum would take up; then diluting the Solution with ten or twelve times its own weight of Water, we put Iron Plates into it, which precipitated the Copper in fine Powder: This Powder was edulcerated, or waſhed, in ſeveral Waters, to clear it of its adhering Salts; and afterwards dried, then ground in a Stone-Mortar, along with an equal weight of Quickſilver: But no Amalgamation enſued. It has been uſually thought difficult, and by ſome impracticable, to make an Amalgam of Copper, by Heat: In which method, indeed, it is not eaſy to ſucceed perfectly; the Copper requiring ſuch a Heat to keep it fluid, as will exhale the Mercury; which otherwiſe does not readily unite with that Metal. In the preſent method the thing may be effected without Heat; *viz.* by firſt reducing the Copper to an exceeding fine Powder; which here ſupplies the place of Fuſion; and might put us upon enquiring whether Trituration may not, in ſome other caſes, be advantageouſly ſubſtituted for Fuſion.

*Its Uſe.*

53. This uncommon Experiment of M. *Homberg* ſhews us a method of advancing Copper ſome degree nearer to Gold; ſo as to fit it for Watch-work, Cane-heads, Snuff-boxes, and the ſmaller Machines and Utenſils, and extremely well for Gilding. It is remarkable that the Quick-

Quickſilver loſes an eighth of its weight in the operation.

54. The Experiment is here employed as a leading one, capable of ſhewing that uſeful changes may be wrought upon the common Metals; ſo as, in ſome meaſure, to introduce a new Set. 'Tis known to ſome, that Copper may be ſo far whitened and ſoftened, as to ſerve on many occaſions for Silver. Lead, by a ſlight application, is capable of being whitened, hardened, and rendered more uſeful for many purpoſes. And if perſons acquainted with the nature and effects of Metals, Minerals, and their Fumes upon each other, were to proſecute the Enquiry, many uſeful things of the like kind might doubtleſs be diſcovered. *Extended.*

55. A little prepared or fixed Arſenic will inſtantly whiten Copper throughout; though thus indeed the Copper proves brittle, or rotten: But there are other ſecret ways of whitening it, ſo as to leave it extreamly ductile. *Exemplified.*

56. The farther proſecution of this Subject would lead us into the ſublimer Metallurgy; which is a part of Chemiſtry by no means hitherto cultivated as it deſerves; as being highly capable of enriching the known mechanical Arts, and ſtriking out new ones. *The Proſecution recommended.*

## III.

57. We now come to offer a few *Rules* for conducting chemical Experiments in the way of an Art; ſo as to improve the ſeveral Branches of Chemiſtry above mentioned *. *Rules for improving Chemiſtry and Arts.*

58. Let the firſt Rule be, with care and diligence, to obſerve the Proceſſes uſed by Nature *Rule I.*



* §. 2, &c.

in the production of all thoſe things we would endeavour to imitate: For Nature, as a moſt expert Chemiſt, employs the very inſtruments which Men alſo employ; *viz.* Fire, Water, Air, and Earth; as we have ſhewn in our Lectures upon the Elements.

*Illuſtration.* 59. To illuſtrate this Rule by an Example, it appears, by numerous inſtances, that there is an acid or ſaline Liquor naturally contained in the Bowels of the Earth; which acid there mixing with various kinds of earthy matters, as a Menſtruum, changes their natures, or makes them appear under different forms. And hence common Brimſtone, Alum, the native Vitriol, *&c.* ſeem to have their origin.

*Illuſtration.* 60. For by an exact ſcrutiny, and attentive conſideration, it appears that when this general Acid diſſolves a certain bituminous Earth, it makes Brimſtone; when a chalky Earth, Alum; when Iron or Copper, Vitriol; *&c.* And accordingly, by uſing the ſame kind of general Acid (which may be procured by burning Brimſtone under a glaſs Bell) in the ſame manner as Nature ſeems to employ it, we can likewiſe, by Art, produce Brimſtone, Alum, or Vitriol, when and where we pleaſe. And thus, if we could univerſally diſcover the Proceſſes and Inſtruments which Nature employs in the production of her effects, we ſhould have certain Rules for imitating her.

*Rule* II. 61. Our ſecond Rule is, To gain a habit of transferring, diverſifying, enlarging, and improving an Experiment, till it ends in ſome certain Diſcovery, either of light to the Underſtanding, or of uſe in Life; one of which points all juſt Experiments will end in, when duly proſecuted and conſidered.

62. For

62. For unſucceſsful Experiments are no leſs inſtructing than thoſe that ſucceed: Which ought to be well remarked. The Head muſt in all caſes co-operate with the Hands: So that the Mind ſhould be ever caſting about to diſcover the cauſes of failure, as well as of ſucceſs. And this is a ſagacity which may be procured by uſe, and turned into a habit of invention and diſcovery: So that no ſingle Experiment ſhall be performed, but ſome advantage will be immediately derived from it; nor no Experiment be made, without ſome ſolid grounds of hope for ſucceſs. *Illuſtration.*

63. Our third Rule is, To proſecute Experiments in an orderly ſeries, with a view to ſome particular Enquiry, of uſe in Life; and to let the Enquiry ſuit the genius and temper of the Enquirer; ſo as that it may be proſecuted by him with vigour and pleaſure. *Rule* III.

64. Thus, if any one ſhould be averſe to the uſe of Fire and Furnace, he may ſtill improve Chemiſtry and Arts, or perform many ſerviceable chemical Operations, without much Apparatus, or expence, or without the Utenſils and Inſtruments commonly employed in that Art: Which may, therefore, be practiſed as well in a Study or Parlour, as in a Laboratory. And to thoſe diſpoſed to operate in this way, may be recommended the buſineſs of Fermentation, the Concentration of Liquors by Cold, and the proſecution of the Nature and Hiſtory of Cold, begun by Mr. *Boyle*. We might alſo recommend the extracting of the finer Eſſences of Vegetables; the making of the more noble and ſpirituous Infuſions, Tinctures, and Elixirs; the examining and tabling the ſolutive power of Water with regard to Salts, and of Spirit of Wine with *Illuſtration.*

regard to different Oils and Roſins; the determining the force of all the known Menſtruums in the Cold; the diſcovery of new Menſtruums, and particularly a Solvent for the Stone. Theſe, and many other chemical Enquiries, may be proſecuted without the uſe of Fires and Furnaces: And even ſuch tempers as are more delighted with ſpeculation than practice, may greatly contribute to the improvement of Chemiſtry, by ſorting, ranging, and digeſting Experiments into Tables; ſhewing what they prove, and how far they reach; how far they fall ſhort, and how they may be carried farther: Others might, to advantage, employ themſelves upon drawing things of uſe in Life, from the Experiments already known and publiſhed: And laſtly, others might, from a due conſideration of Experiment, deduce new Directions and Rules of Practice for producing, in a ſure and conſtant manner, much greater Effects than are uſually hoped for.

## AXIOMS and CANONS.

1. We learn from the preſent Lecture, that Chemiſtry is an Art of very extenſive uſe in Life; inſomuch that not only Natural Philoſophy, but alſo Trade, Commerce, and active Buſineſs, have a dependence upon it, and may be improved by it *.

2. That therefore the diſeſteem which Chemiſtry has generally met with, proceeds from a want of knowing its proper office, extent, and uſefulneſs; and from the frequent miſapplication

* See the whole Lecture *paſſim*.

tion of it to things of a delusory or phantastical nature.

3. That a large part of general Chemistry may be advantageously practised, and many Discoveries and Improvements made therein, for the service of Arts, without the direct use of Chemical Fires, Furnaces, and the common *Apparatus* *.

4. That numerous Discoveries and Improvements remain to be made in Chemistry it self; and that these Improvements may be made in a direct, rational manner; and if once made, might greatly enlarge and illustrate Natural Philosophy, improve various Arts, and introduce a new Set †.

5. That in particular Sal-Ammoniac, an Amber-Varnish, a hard kind of Glass, a Foil for Glasses, an excellent Glue, and a new kind of Metal, may be easily obtained, for the improvement of Pharmacy, Dying, Japanning, Embalming, the Art of Glass, the making of artificial Gems, the foiling of Glasses, the gluing of Timber, Embossing, the taking off Impressions, the Art of Watch-making, and other mechanical uses.

6. That the Canons for the farther improvement of Chemistry, and the Arts thereon depending, require, (1) a careful observation of the ways of working employed by Nature; (2) a talent of Experimenting; and (3) the discretion of suiting the Enquiry to the temper and genius of the Enquirer §.



* See §. 12, 13. and Exp. II. IV. V. and §. 63, 64.
† See the whole Lecture. § See §. 58——64.

## *CONCLUSION.*

WE are now come to the end of our Lectures; where it may be proper to ſtand a while, and look back upon the ground we have gone over. We ſeem to our ſelves to have been travelling in a new Road, too little frequented either by Philoſophers, Chemiſts, or the Men of Buſineſs. Our endeavour has been to improve the uſeful Arts, by means of a more Philoſophical Chemiſtry; and at the ſame time to ſhew the Method of conducting Enquiries, ſo as that they may terminate in uſeful Diſcoveries. With an eye fixed upon this End, we have purpoſely avoided the more entertaining and agreeable Experiments, wherewith Chemiſtry abounds; and kept to ſuch only as were judged either in themſelves beneficial, or of ſervice in diſcovering Cauſes, Axioms, and Rules. And if there be any Merit in what we have done, we own it to be a borrowed one; and apprehend that it lies in the *Verulamian* Method we have purſued, or in endeavouring to rectify the Mind, guard it againſt Error and Illuſion, and conduct it to the Fountains of Nature and Uſe. We cannot indeed preſume to have diſcovered many of the true Cauſes of Things, nor Axioms perfectly juſt and univerſal: To do this, requires that the ſeveral parts of Philoſophy ſhould be better laboured than they are. All we can hope for is, to have found ſome few ſuch Rules as may direct to a ſerviceable Practice; and enable us to enrich and improve ſome few of the preſent Arts and Sciences: Thus, for Example, we hope to have diſcovered this philoſophical Axiom, That *Sugar, or a ſaccharine*

*Sub-*

*Subſtance, is the Baſis of Wines, Beers, Vinegars, and inflammable Spirits:* Whence we preſume, that the Arts of Brewing, Wine-making, Vinegar-making, and Diſtilling, may receive a great degree of Perfection. And thus we deſire to have it obſerved, that the Diſcovery of a ſingle Axiom, or Cauſe, may often improve, or even perfect, a number of Arts: For phyſical Axioms, duly diſcovered, may be pregnant with the Matter of many Arts and Sciences. And on this account it is, that we have directed our Enquiries to the Inveſtigation of them; as the beſt and ſureſt means of improving the known Arts, and diſcovering new ones. Doubtleſs, if this Method were carefully and generally purſued, the Buſineſs of Invention would not long continue that caſual thing it is; but be reduced to an Art, which, of all others, is, perhaps, the moſt wanted.

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